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.D.A. Forest Service RESEARCH NOTE

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GROWTH OF FROST-DAMAGED DOUGLAS-FIR SEEDLINGS

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by

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ABSTRACT

A hard frost in September 1965 severely damaged Douglas-fir seedlings at the U.S. Forest Service's Wind River Nursery near Carson, Wash. Damaged and undamaged seedlings were outplanted later the same fall and next spring. Their height growth in the next three seasons indicated that (1) some damage to Douglas-fir seedlings is hidden and cannot be identified visually months after frosting occurs; (2) even when obvious, damage may not handicap future seedling growth; (3) subsequent growth seems affected most when seedlings are lifted soon after being frosted; (4) multiple tops resulting from frost damage may be relatively unimportant. It is recommended that Douglas-fir seedlings recently damaged by frost should not be culled too heavily, else seedlings with excellent juvenile growth potential will be discarded.

INTRODUCTION

A hard, early frost on September 9, 1965, severely damaged many Douglas-fir seedlings growing in the Wind River Nursery near Carson, Wash. Seedlings from nearly all seed sources were affected--those from high elevations or east of the Cascade Mountains were damaged least; those from low elevations in the Cascade and Coast Ranges suffered most.

When grading freshly frosted seedlings or transplants, nurserymen usually cull heavily because they feel that the reduced needle complement may affect field survival and growth, or that injury to leaders and terminal buds might cause development of multiple tops. However, a literature search yielded no reports on growth of seedlings outplanted soon after being frosted in the nursery and little concerning development or persistence of multiple tops following such injury.

Two studies established in 1965-66 following the frost provided data on growth potential of frosted seedlings. In one study, seedlings apparently free of frost damage were used; in the other study, growth of damaged and undamaged seedlings was compared.

PLANTING-DATE STUDY

Methods

Survival and growth of 2-0 Douglas-fir seedlings planted at 6-week intervals from late October to early April were compared in a planting-date study. Seedlings from a 5,000-foot elevation source which had apparently sustained minor frost damage were planted on the Columbia Gorge District, Mount Hood National Forest. Two blocks were laid out in one clearcut; each contained five plots. On each of five dates, 10 freshly lifted seedlings were planted in each plot for a total of 100 seedlings per date. Each tree was protected from deer and rabbits by poultry netting 2 feet high, closed at the top.

Results and Discussion

An unexpected phenomenon occurred in the spring of 1966--terminal buds on 51 percent of the surviving trees failed to burst. Bud failures ranged from 61 percent on seedlings lifted and planted in January to 33 percent on those lifted and planted in April:

Month planted	Live seedlings	Terminal buds failed
	(Number)	(Percent)
October	[1]39	59
December	91	55
January	93	61
March	94	54
April	97	33

[1] Cause of excessive mortality in October was traced to dry soil at planting time.

In assessing bud failure, there is reason to wonder if a nursery condition other than frost, or a condition related to the planting site, was involved. Both nursery and planting site were snow-free during the October and December plantings, but January, March, and April plantings were made with trees lifted from under 5 feet of snow. In January, snow also had to be cleared from the planting spots. In view of frost and snow conditions at the nursery, all seedlings were examined carefully before planting. Seedlings scraped or broken by snow shovels as well as those with buds shrivelled or needles browned by frost were rejected. Thus, bud failures occurred among seedlings that appeared undamaged when planted, and the frost was judged responsible for these failures.

The second unexpected phenomenon came to light when height growth data for three seasons were analyzed. Data for seedlings which failed to burst bud in 1966 were summed separately from data for those whose terminal buds had burst. The largest difference in average initial height of damaged and undamaged seedlings within a single planting was only 1.7 centimeters, but subsequent differences in height growth were much larger (table 1). In October, December, January, and March plantings, undamaged trees grew more than damaged trees by 7.0, 7.8, 6.5, and 3.7 centimeters, respectively. In the April planting, damaged trees grew 2.9 centimeters more than undamaged trees. Height growth in all plantings reached near-normal rate by the third season, with damaged trees of the April planting showing the largest increment.

Total height growth also varied by month of planting. Undamaged trees planted in October, December, January, March, and April grew 60.3, 49.0, 42.0, 48.8, and 57.4 centimeters, respectively; damaged trees planted in the same months grew 53.3, 41.2, 35.5, 45.1, and 60.3 centimeters, respectively.

FROST-DAMAGE STUDY

NURSERY PHASE

Methods

Fifty-six trees without frost damage were paired with 56 similar but damaged trees. Needle length, color, and apparent complement, stem diameter, and total height were the criteria used for pairing seedlings. Only those with terminals obviously withered by frost were chosen to represent damaged trees. The 2-0 seedlings, from a Siskiyou National Forest source, were lifted, paired, and replanted the same day in April 1966, about 7 months after frost damage. Trees were spaced approximately 3 feet by 3 feet apart in seven rows of 16 trees each at Wind River Nursery. Members of pairs were planted one following the other within the row to minimize effects of microsite differences. Trees were not irrigated or weeded during the study.

Total height was not recorded when trees were planted because frost-damaged trees varied in live height, and there was no indication where new leaders would arise. In fall 1967, total height and seedling height at the point of origin of the now identifiable new leader were recorded. Point of leader origin and the 1966 terminal bud scars were considered as marking the 1966 height of damaged and undamaged seedlings, respectively.

Table 1.--*Average height and accumulated growth of undamaged and damaged*[1] *2-0 Douglas-fir seedlings planted in 5 different months*

(In centimeters)

Year	October		December		January		March		April	
	Undamaged	Damaged	Undamaged	Damaged	Undamaged	Damaged	Undamaged	Damaged	Undamaged	Damaged
1965	29.8	28.1	29.4	30.4	26.8	27.3	26.7	28.1	24.1	23.3
1966	35.6	32.1	34.4	33.3	31.1	29.9	31.5	31.2	29.6	27.8
1967	57.5	50.2	53.8	48.6	47.5	43.6	49.3	47.2	50.2	47.6
1968	90.1	81.4	78.4	71.6	68.8	62.8	75.5	73.2	81.5	83.6
3-year growth	60.3	53.3	49.0	41.2	42.0	35.5	48.8	45.1	57.4	60.3
Growth difference	-7.0		-7.8		-6.5		-3.7		+2.9	

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[1] Seedlings which failed to burst bud in the first season, apparently because of hidden frost damage.

Tree heights were last measured in fall 1968. Yearly observations of damaged and undamaged trees were also made to determine relative number of seedlings with multiple tops or late flushes of growth.

Results and Discussion

No seedlings died during the study; and at the end of one growing season, fall 1966, undamaged trees averaged 29.4 centimeters tall compared with a 19.2-centimeter live height for damaged trees. In the 1967 and 1968 seasons, undamaged trees grew 19.9 and 37.2 centimeters, respectively, and damaged trees grew 24.5 and 46.8 centimeters (fig. 1). In 2 years, damaged trees made up their 10.2-centimeter handicap, gained an additional 4.0 centimeters, and averaged 90.5 centimeters tall; whereas undamaged trees averaged 86.5 centimeters tall. The statistical odds that this growth difference is real are better than 1,000 to 1.

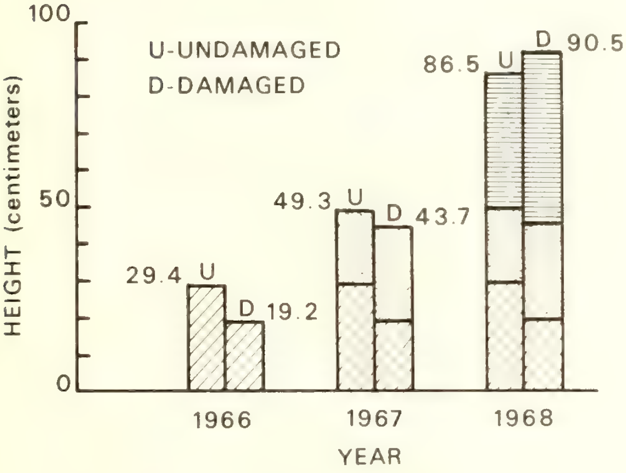

Figure 1.--*Average height at yearly intervals after planting undamaged and frost-damaged 2-0 Douglas-fir seedlings.*

Frost-damaged seedlings are prone to develop multiple tops when resuming height growth after damage. In fall 1967, 34 percent of the frost-damaged trees had multiple tops compared with 5 percent of the undamaged trees. One year later, 28 percent of the damaged trees and again 5 percent of the undamaged group had multiple tops. These figures suggest that multiple tops caused by frost damage do not persist.

In 1967, 91 percent of the damaged trees put on a second flush of growth, compared with 57 percent of the undamaged trees. Corresponding percentages for 1968 were 45 and 18, respectively. These differences suggest that trees were damaged originally because they were in a succulent state when the frost occurred; those that escaped damage had probably already set a frost-resistant bud.

GROWTH CHAMBER PHASE

Methods

Growth of 15 frost-damaged seedlings rejected by graders at the nursery was compared with that of 15 frost-damaged seedlings which had been accepted. Rejected seedlings all had some live foliage but somewhat less than those that met grading standards. Seedlings were planted individually in 4-inch pots and placed randomly in a Percival environator[1] where they were grown for 14 months under 1,400-foot-candle illumination for 16 hours per day at 85° F. and 8 hours per night at 60° F. Seedlings were then depotted. Original tops and new growth were separated, ovendried to constant weight at 158° F. (70° C.), and weighed.

Results and Discussion

When placed in the growth chamber, accepted seedlings had an apparent live height of 12.4 centimeters and total height of 17.5 centimeters; rejected seedlings, 8.8 and 14.3 centimeters (fig. 2). After 14 months, weight of the original top (including dead material) averaged 1.92 and 1.27 grams for accepted and rejected seedlings, respectively. These figures show that graders at the nursery tended to accept the larger damaged seedlings and reject the smaller ones.

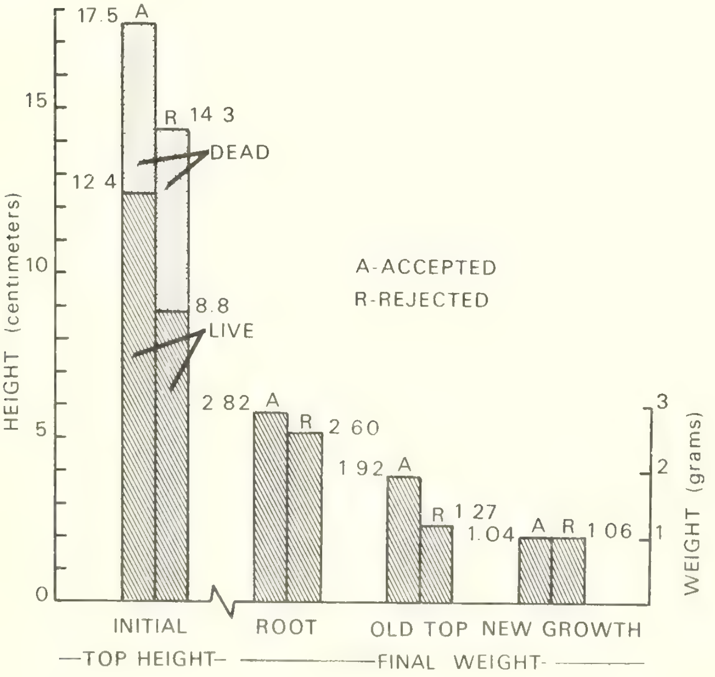

Figure 2.--*Initial height and top and root weight 14 months later of 15 accepted and rejected 2-0 Douglas-fir seedlings damaged by frost.*

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[1] Mention of products by name does not consitute an endorsement by the U.S. Department of Agriculture.

However, total weight of new top growth produced by accepted and rejected seedlings averaged 1.04 and 1.06 grams, respectively, and final weight of roots averaged 2.82 and 2.60 grams. Only one seedling, an accepted one, died. These data demonstrate that there was no difference in growth potential between the accepted and rejected groups of seedlings.

SUMMARY AND CONCLUSIONS

Four points brought out by the two studies deserve emphasis: (1) Some damage to Douglas-fir seedlings is hidden and cannot be identified visually months after frosting occurs; (2) even when obvious, damage may not handicap future seedling growth; (3) subsequent growth seems affected most when seedlings are lifted soon after being frosted; (4) multiple tops resulting from frost damage may be relatively unimportant.

Seedlings injured by frost and lifted soon afterwards grew less in height during the first three seasons than uninjured seedlings lifted at the same time; those lifted the longest time after damage occurred grew more than uninjured seedlings lifted at the same time. This suggests that initial recovery is important and that such recovery can be facilitated by leaving the damaged seedlings in the undisturbed nursery bed as long as practical. Study data do not indicate that 2-0 seedlings moderately damaged in the fall need be held through another season in the nursery bed, however.

The tendency for more damaged than undamaged trees to double-flush suggests that they were faster growing prior to being damaged. In fact, their tendency to double-flush is probably the reason they were damaged--their tops may still have been succulent when frost occurred whereas tops of those having a single flush of growth probably were partially or fully hardened off.

Development of multiple tops on frost-damaged Douglas-fir seedlings may be only a trivial matter. Other damaging agents also cause multiple tops--for instance, animal browsing. Our observations and those of others suggest that a single top may assume dominance on damaged trees in a short time. The rarity of older Douglas-fir trees with forks near the ground provides further evidence that multiple leaders on seedlings of this species are of fleeting importance.

Nurserymen and field foresters have no proven criteria for grading frost-damaged seedlings. Since many terminal buds are killed by frost yet show no visible evidence of damage, graders cannot cull all frosted trees even if they think they should. Furthermore, these studies demonstrate that many frost-damaged seedlings should not be culled. Frost-damaged seedlings appear to have been the fastest growing ones before they were damaged and to remain so after damage. If this is so, it would be a mistake to discriminate against all frost-damaged trees in nursery grading. Not only would we be throwing away trees with good juvenile growth potential in an era when rapid growth is receiving increased emphasis, but we might also be removing desirable growth traits from the next generation of trees.

How much height or needle complement frosted seedlings can lose and still fully recover remains an unanswered question. Until more definitive work can be done on frost damage, the message is: Don't cull frost-damaged Douglas-fir seedlings too heavily; some of them may be our fastest growing stock.

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AN AUTOMATIC PHOTOELECTRIC TRIGGERING MECHANISM FOR A DATA-RECORDING CAMERA

by

W. Y. Pong, R. M. Bass, and H. D. Claxton[1]

ABSTRACT

An automatic photoelectric triggering mechanism was designed and developed for a data-recording 35 mm pulse operated camera recording information about individual pieces of lumber as they are produced in sawmills This triggering mechanism does not physically contact boards moving on the conveyor chains and will operate for any random spacing of boards

Photographic recording of data is particularly useful where numerous repetitions of data or information must be documented over long periods of time. Such a technique is well suited for recording lumber production information needed in sawmills. Detailed information about each piece of lumber moving on conveyer chains (fig. 1) is easily, accurately, and permanently recorded.[2]

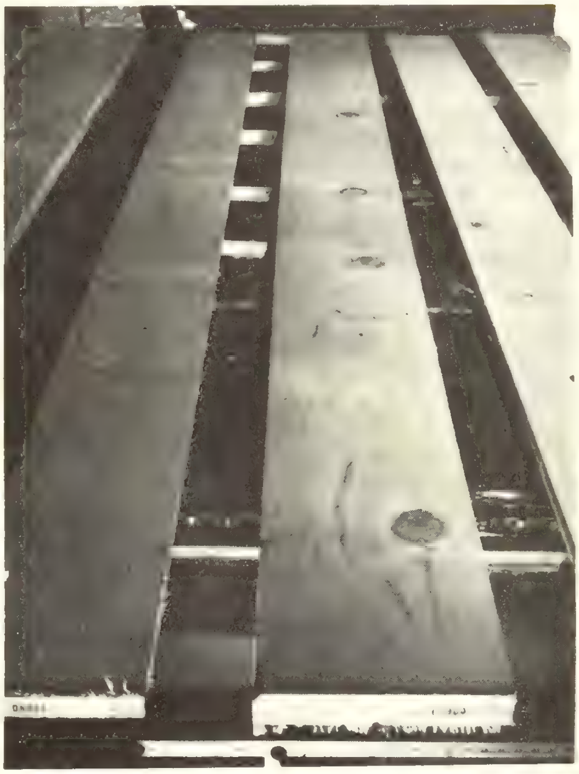

Figure 1.--*Photo record of lumber on conveyor chain in a sawmill. Board number, grade, length, width, and thickness are permanently and accurately recorded.*

Development of a satisfactory photographic technique for application in sawmills had its share of technical problems. Many of these problems, e.g., the type of camera, correct exposure for a given film and lighting condition, best film types for detail resolution, were solved by trial and error; others required further equipment development to make the whole system more compatible for use in sawmills and to reduce the probability of equipment failure.

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[1] The authors are, respectively, Forest Products Technologist, Pacific Northwest Forest and Range Experiment Station; Electrical Engineer, formerly with Pacific Southwest Forest and Range Experiment Station; and Research Forester, Pacific Southwest Forest and Range Experiment Station.

[2] Harvey H. Smith. Photographic data recording in mill studies. Unpublished Pacific Southwest progress report, 10 pp., illus. 1964.

One difficulty encountered in early models of the system was the fragility of the triggering mechanism used to trip the pulse-operated camera and other auxiliary equipment. Triggering was accomplished by a microswitch mounted on the conveyor chain (green chain) and depressed by boards moving on the chain. As the repetitious physical impact of the boards on the switch made it vulnerable to breakage, it was necessary to install an additional manually operated pushbutton switch parallel with the microswitch. This switch permitted triggering the photographic data recording system on command in case of microswitch failure. The switch was also used whenever spacing between boards was not sufficient to permit the microswitch to reset after each photograph. A triggering mechanism of this type required the full attention of one man.

Because of the fragile nature of this triggering mechanism and the attention it required for proper operation, a different type of mechanism for tripping the camera was designed and developed which did not in any way make physical contact with boards moving on the green chain and was completely automatic.

GENERAL DESCRIPTION

Basically, the new triggering mechanism consists of a light beam and photoelectric relay and a pulse generator. These are electrically connected to the pulse-operated camera, strobe light, and power supply through a junction box (diagramed in fig. 2A). In operation (fig. 3), the electrical pulse needed to activate the camera is first initiated with the interception of the light beam directed on the photoelectric relay. With the closing of the photoelectric relay, the pulse generator is then activated to produce the necessary electrical pulse for the camera.

PHOTOELECTRIC RELAY AND LIGHT BEAM

The photoelectric relay and light beam can be any one of a number commercially available. We used a Sigma Series 8 PL 2 (fig. 4) operating on 110 VAC, 60 cycles.[3] The photocell in this unit is a cadmium sulfide photoconductive cell which activates an electromagnetic relay. A light level of 5 footcandles or more is needed to operate the photoelectric relay; the companion light source produces this level at a maximum height of 12 feet.

Trials at lumber mills demonstrated that best results were obtained when the photoelectric relay was mounted at the green-chain level and the light source mounted 6 to 8 feet above and directed down on the photocell. Because the photocell was too sensitive to stray light, a blackened metal cylindrical shield with a 1/2-inch hole was used to cover the metal lens housing of the photoelectric relay (see fig. 4). Mounting the photoelectric relay on the outer edge of the green-chain floor with a 1/2-inch clearance between the top of the shield and the bottom of the moving boards virtually eliminated premature triggering.

The photoelectric relay was so wired that all contacts were normally closed (i.e., no light on the photocell). Output leads from the photoelectric relay to pins A, B, C, and D were permanently wired together at the 110 VAC plug of the photoelectric relay (see fig. 2A). Because of this it was necessary to observe polarity in wiring the pulse generator (see fig. 2A and table 1).

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[3] Mention of products by name does not represent endorsement by the U.S. Department of Agriculture.

PULSE GENERATOR

In designing the pulse generator, a number of physical and functional features were incorporated. As compactness was important, the complete unit was designed to fit in a stainless steel box measuring 8 by 8 by 6 inches (see fig. 5). Internal wiring was number coded for easy reassembly, and external electrical connections were color coded, matched, and labeled to prevent errors in connecting auxiliary equipment. A frame counter was installed to register the number of exposures made by the camera.

The pulse generator consists of two major components and one major circuit (see fig. 3). These are a time delay relay (TDR) which is a slow-action relay, a pulse-shaping timer relay, and the uni-junction transistor (UJT) circuit. The timer relay is activated by either the TDR or the UJT circuit (see figs. 2A, 2B and 2C), each of which becomes operative only under certain green-chain conditions.

Time Delay Relay

The time delay relay (TDR) (see figs. 2A and 2B) becomes operative each time a "make and break" situation develops at the photocell. This condition occurs whenever there is a series of spaced boards on the green chain. The passage of each board between the light source and the photocell closes the photoelectric relay. When this happens, the TDR is activated. There is a preset delay between the closing of photoelectric relay and the subsequent operation (opening) of the built-in single-pole double-throw (SPDT) relay (normally closed) in the time delay relay. This delay allows a pulse current (110 VAC) to activate the timer relay (see fig. 2A). Thereafter, as long as the photoelectric relay remains closed (no-light condition) the time delay relay will remain open; it resets instantaneously upon the opening of the photoelectric relay with the passage of the board.

The time delay relay used in the present triggering mechanism was an Industrial Timer Series TRP-5 plug-in, adjustable delay relay operating on 110 VAC, 60 cycles (figs. 2B and 5). The delay time of this particular unit is adjustable from 0.1 to 5 seconds. A 0.1-second delay was found adequate for activating the timer relay. Wiring details of the time delay relay are shown in figures 2A and 2B and table 1.

Uni-junction Transistor Circuit

The uni-junction transistor (UJT) circuit is a timing circuit for triggering the camera under certain green-chain conditions. If all boards to be recorded are spaced on the green chain to allow a "make and break" situation at the photocell, only a time delay relay electrically connected to a timer relay would be necessary to trigger the camera and auxiliary equipment. In practice, however, often a series of boards is unspaced, and under these conditions, only the lead boards would be recorded.

To provide for an unspaced series of boards on the green chain, a separate solid state circuit was designed which would generate at regular intervals the 110 VAC pulse necessary to activate the timer relay (see fig. 2A). This circuit becomes operative only after the TDR pulse expires and the latter relay remains open for a predetermined length of time activated by either an exceptionally wide board or an unspaced series of boards passing over the photocell. As long as the TDR remains open, the UJT circuit will continue to generate at regular intervals the electrical pulse necessary to activate the timer relay.

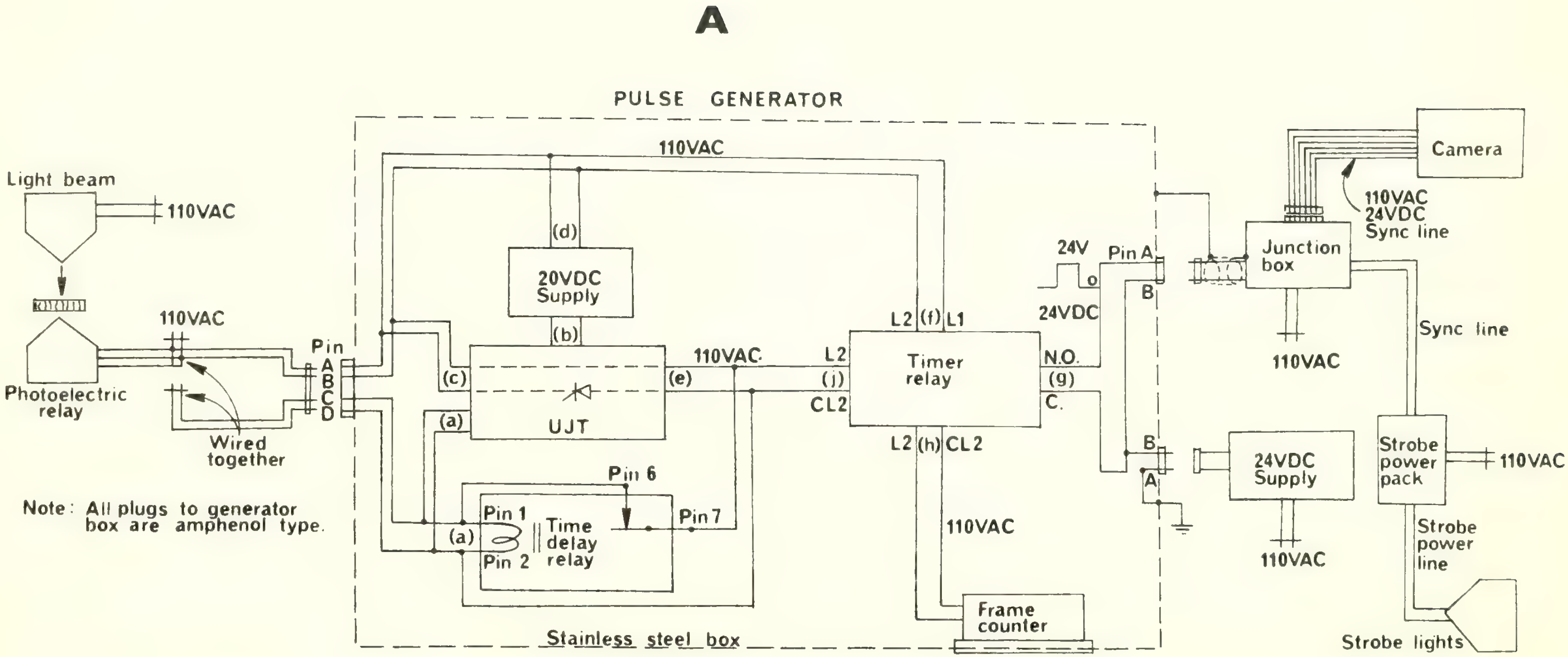

Figure 2A.--*Diagrammetric layout of a complete photographic data recording system with component details for the triggering mechanism.*

B

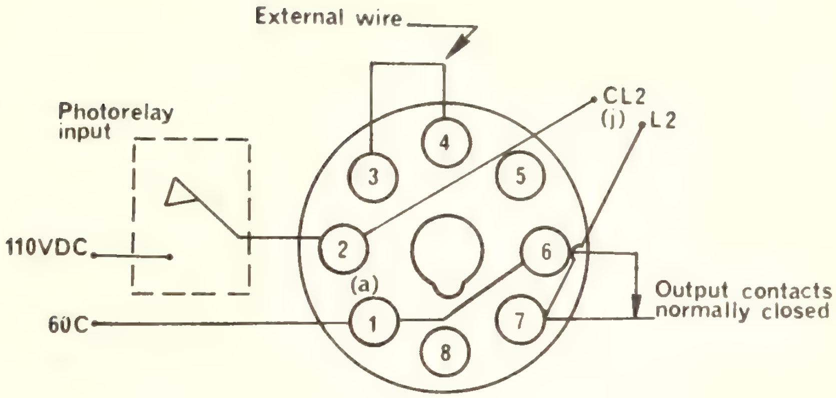

Figure 2B.--*Wiring details of the base of the time delay relay.*

C

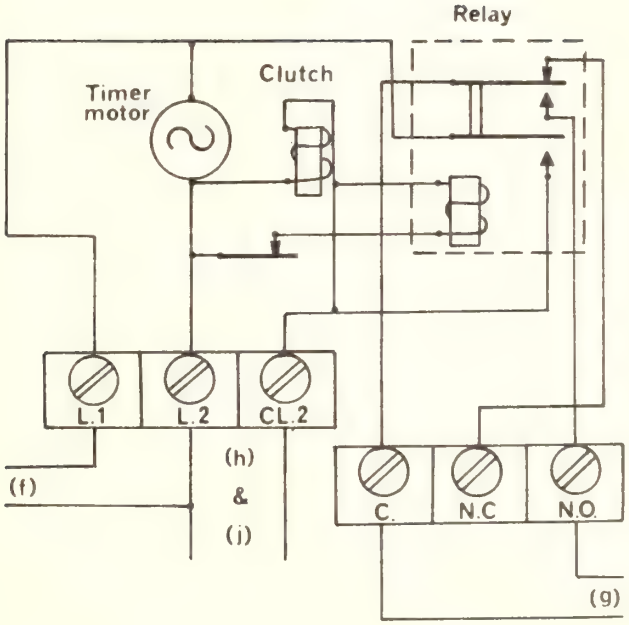

Figure 2C.--*Wiring details of the timer relay.*

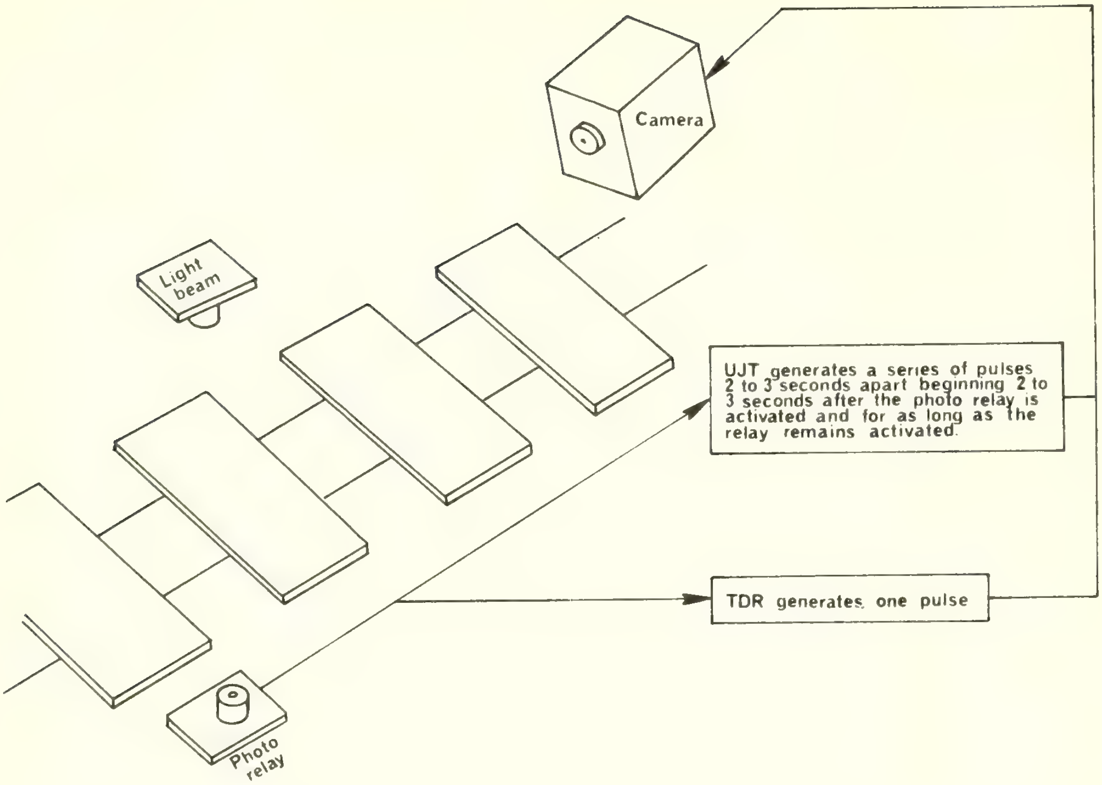
Camera
Light beam
UJT generates a series of pulses 2 to 3 seconds apart beginning 2 to 3 seconds after the photo relay is activated and for as long as the relay remains activated.
TDR generates one pulse
Photo relay

Figure 3.--*Block diagram of the pulse generation path in the photographic data recording system.*

Table 1.--Wiring chart for pulse generator: location and component connections

Location	Component connections
(a)	UJT - see figs. 2A and 6; TDR - pin 1 and 2, see figs. 2A and 2B
(b)	UJT - see figs. 2 and 6; 20 VDC supply - see fig. 7
(c)	UJT - see figs. 2 and 6
(d)	20 VDC supply - see figs. 2 and 7
(e)	UJT - see figs. 2 and 6
(f)[1]	Timer relay, L1 and L2 - see figs. 2A and 2C
(g)	Timer relay, N.O. and C. - see figs. 2A, 2C, and 8
(h)	Timer relay, L2 and CL2 - see figs. 2A and 2C
(j)[1]	Timer relay, L2 and CL2 - see figs. 2A, 2B, and 2C

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[1] Since leads to (f) and (j) are permanently wired together at the photoelectric relay plug, polarity must be observed.

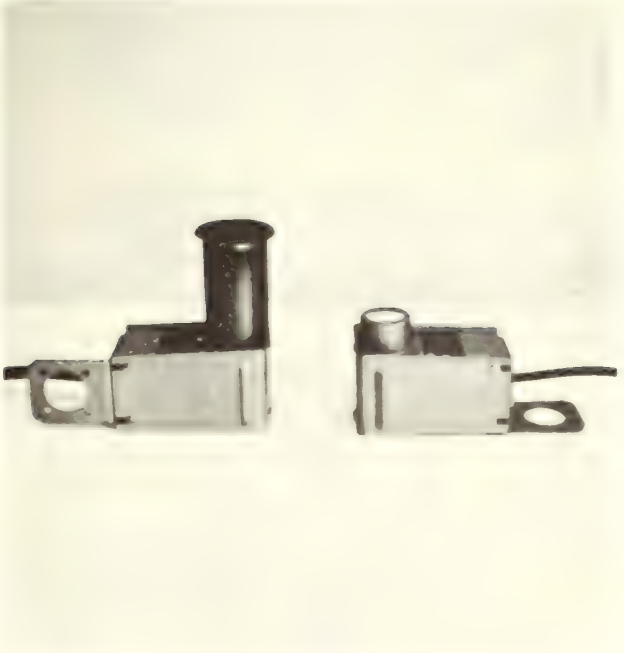


Figure 4.--*Photoelectric relay (left) and light beam (right) used in automatic triggering mechanism.*

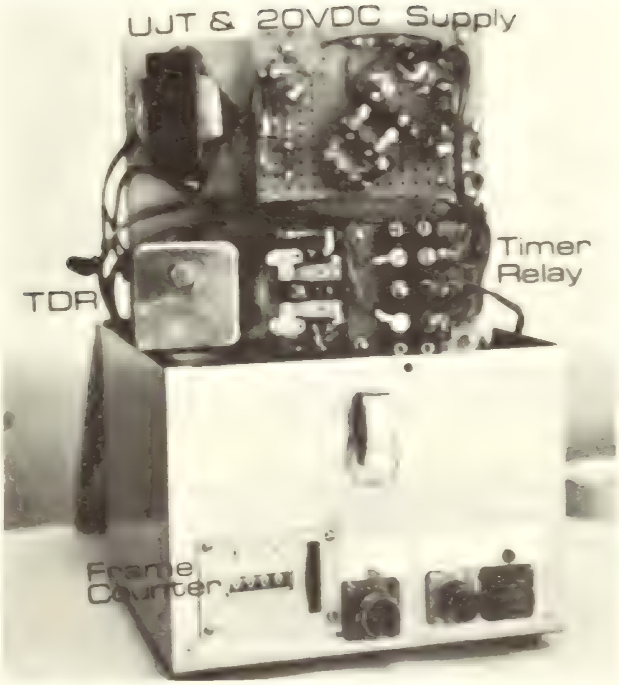


Figure 5.--*Placement of components used in the pulse generator.*

Details of the UJT circuit and its power supply are presented in figures 6 and 7. The placement of the components in the circuit is shown in figure 5.

In actual operation, the UJT circuit can be described as follows (see fig. 6): The closure of the photoelectric relay results in the closing of the relay in the UJT circuit. When this occurs, the 200 µf capacitor begins to take on a charge from the 20 VDC supply. The rate at which the capacitor is charged is controlled by the 10 K variable resistor incorporated in the circuit. The capacitor discharges suddenly through the 2N1671B uni-junction transistor when the critical or "avalanching" voltage of the transistor (approximately 0.4 of the supply voltage or 0.4 x 20 = 8 volts) is reached during the charging of the capacitor. The transistor then conducts, activating the 2N1850 silicon controlled rectifier. This momentarily applies 110 VAC to the timer relay. The duration of the 110 VAC pulse to the timer relay is essentially the discharge time of the capacitor through the transistor (approximately 75 milliseconds) and corresponds roughly to the time it takes the transistor voltage to drop to approximately 4 volts. Once discharged, the capacitor is again recharged; and upon reaching the critical voltage of the transistor, it again discharges. This cycle will continue as long as the photoelectric relay remains closed and the TDR is open.

The UJT circuit cannot operate as long as the photoelectric relay is closed for less time than it takes to charge the capacitor. The charging time selected depends on a number of factors closely tied to the actual study (such as green-chain speed, board size, and working room available) and to limitations of auxiliary equipment (such as lens coverage and recycling time of the strobe power pack). If the charging time selected is not exceeded by the close time of the photoelectric relay, the TDR pulse will be the only pulse which will operate the timer relay; if the charging time is exceeded the UJT circuit will be activated. Tests with the photoelectric triggering mechanism indicate that a 2- to 3-second charge time is adequate for coverage of most green-chain conditions.

Timer Relay

The momentary pulse generated by either the TDR or UJT circuit is not of proper duration and voltage to directly operate the data recorder (fig. 2A). The timer relay accepts the TDR or UJT pulse and generates an electrical pulse output sufficient to operate the relays, shutter, and takeup motor in the camera for a single frame. In the present photographic system, a 35- to 50-millisecond pulse, 24 VDC, is needed. This is supplied by a 24-VDC supply, which is external to the pulse generator but wired to the timer relay through amphenol plugs (see figs. 2A and 5). Details of the 24-VDC circuit are presented in figure 8.

Pulse durations of less than 35 milliseconds are not sufficient to operate the recorder; pulses longer than 50 milliseconds would throw the recorder into "cine" operation, i.e., 10 frames per second. It was essential that a timer relay consistently accurate in providing a 35- to 50-millisecond pulse over long periods of operation be incorporated in the pulse generator. The timer relay used in the present system was an Industrial Timer, Series PAF-1S (figs. 2C and 5) panel-mount interval timer. This particular model is a clutch operated, automatic reset timer relay operating on 110 VAC, 60 cycles, with a maximum time cycle of 1 second in 1/60-second increments. Wiring details of this timer relay are presented in figures 2A and 2C and table 1.

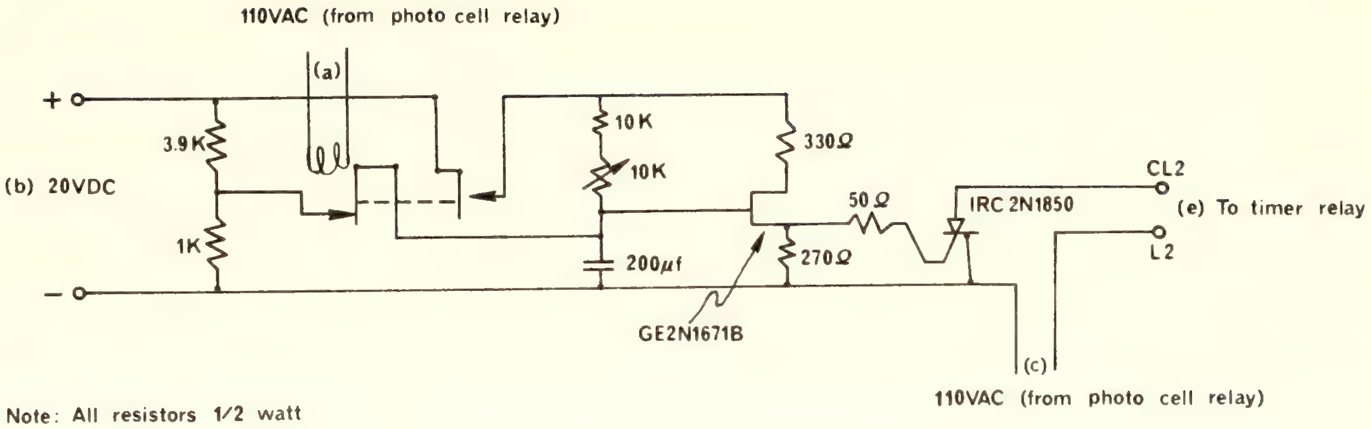

110VAC (from photo cell relay)
(a)
+
(b) 20VDC
–
3.9K
1K
10K
10K
200μf
330Ω
270Ω
50Ω
GE2N1671B
IRC 2N1850
CL2
L2
(e) To timer relay
(c)
110VAC (from photo cell relay)
Note: All resistors 1/2 watt

Figure 6.--*Schematic diagram of the uni-junction transistor (UJT) circuit. Relay is in nonphotographing position.*

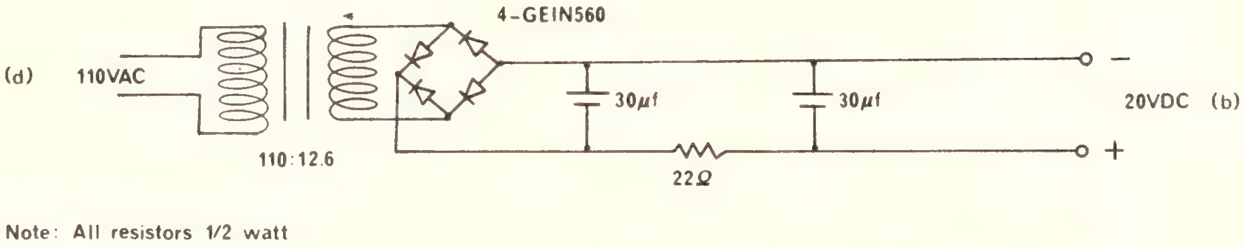


Figure 7.--*Schematic diagram of the 20 VDC supply for the UJT circuit.*

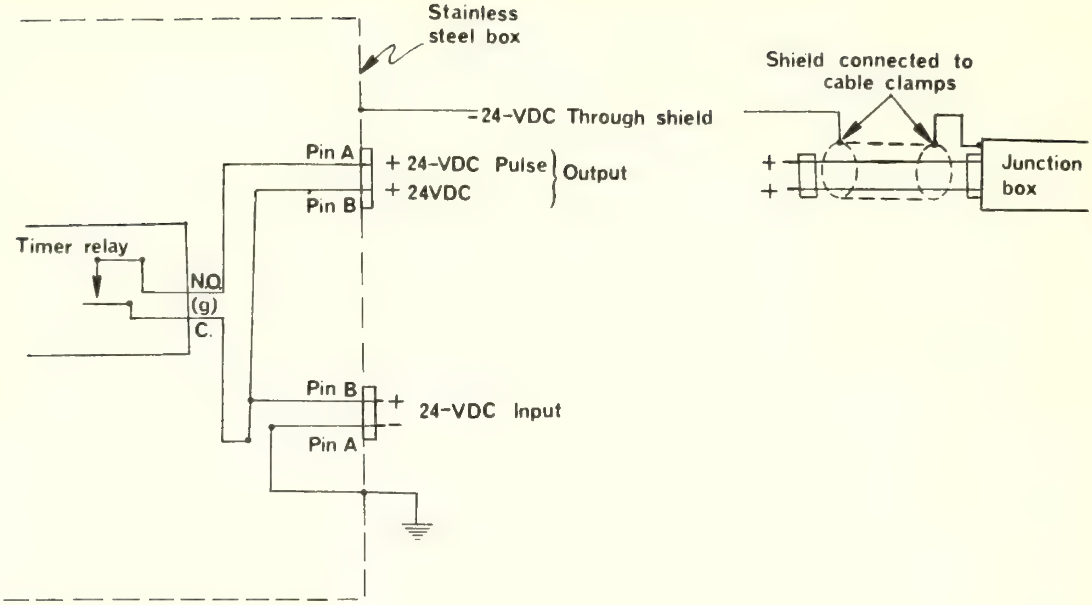


Figure 8.--*Wiring details of 24-VDC circuit.*

Frame Counter

A resetable panel-mounted counter installed on the pulse generator box and connected to the timer relay terminals L2 and CL2 (see figs. 2C and 5 and table 1) registered the number of frames exposed by the camera. The counter operates from the 110 VAC pulse that the timer relay receives from either the TDR or the UJT circuit. Each pulse is equivalent to a single-frame exposure by the camera.

Stability

The pulse generator does not appear to be temperature sensitive. Time between pulses as regulated by the 10 K variable resistor was constant for any one setting and was not affected when tested under refrigeration, at room temperature, and under variable field temperatures. This unit has been pulsed over 21,000 times during a 4-day period in an actual lumber recovery study without failure.

Junction Box

Electrical interconnection of the pulse generator, camera, and strobe unit are centralized through a 2- by 2- by 4-inch junction box (fig. 2A). This junction box also provides 110-VAC power for the camera-drive motor. To prevent misconnecting of the synchronization line at the box, a three-prong amphenol plug was installed (one prong unused) for this line. Wiring details of the junction box are presented in table 2.

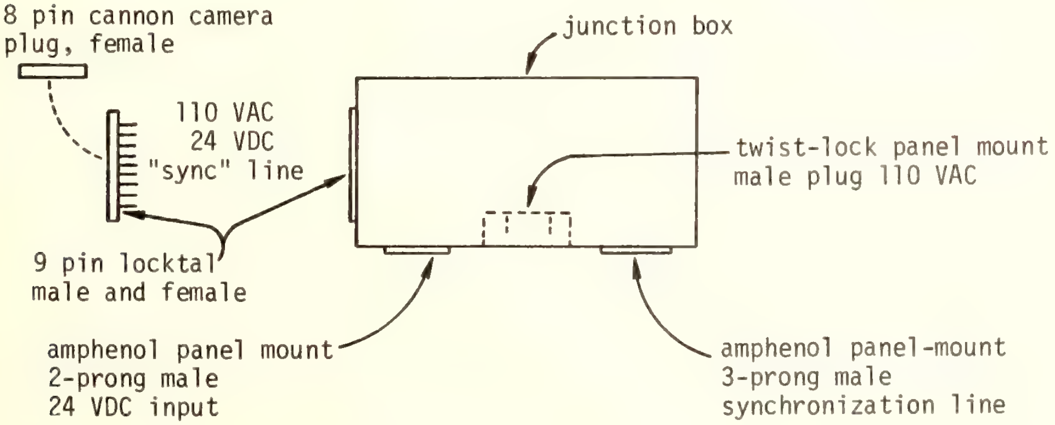
APPLICATION

The photoelectric triggering mechanism has been successfully used with a Traid Automax G-3 pulse-operated camera. This cine pulse camera is similar to the G-1 model described by Smith (see footnote 2), differing only in having a 110-VAC drive motor instead of a 24-VDC motor. When fitted with a wide angle (25- to 35-mm) Kinoptik lens, board lengths up to 28 feet can be obliquely photographed with good resolution. Electrical connections between junction box and the camera are shown in table 2. The power needed to operate the shutter, relays, and takeup motor in the camera is supplied by a 24 VDC source furnished with the camera.

Boards are illuminated by strobe lights which are synchronized with the shutter of the camera. A "sync" line connects the camera and strobe power pack through the junction box (see fig. 2A and table 2). Each pulse received by the camera from the pulse generator trips both the camera shutter and the strobe unit. Any satisfactory strobe unit can be used with the photoelectric triggering mechanism, since the only connection to the system occurs at the junction box via the synchronization line. A Balcar electronic flash, model T-1005, with two heads was used in the present photographic system. At 300 watt-seconds this unit recycles in 0.7 seconds. A constant source of light (e.g., photofloods) may also be used, in which case there is no electrical connection to the recorder.

Table 2.--Wiring chart for camera plug and junction box plugs

9 pin locktal pin number	2-prong (24 VDC line)	3-prong ("sync" line)	Twist lock (110 VAC)	Camera plug 8 pin cannon pin (wire)
1 chassis ground				A (white)
2			x	E (black)
3	+24 VDC pulse B			B (orange)
4	+24 VDC constant A			H (green)
5			x	F (red)
6				D (not used)
7		A		G (blue)
8		B		C (brown)
9 (not used)		C (not used)		


8 pin cannon camera plug, female
junction box
110 VAC
24 VDC
"sync" line
twist-lock panel mount male plug 110 VAC
9 pin locktal male and female
amphenol panel mount 2-prong male 24 VDC input
amphenol panel-mount 3-prong male synchronization line

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D.A. Forest Service RESEARCH NOTE

PNW-123 July 1970

STABILIZATION OF NEWLY CONSTRUCTED ROAD BACKSLOPES BY MULCH AND GRASS-LEGUME TREATMENTS

by

C. T. Dyrness, *Principal Soil Scientist*

CLEMSON UNIV. LIBRARY
OCT 26 1970
S.C. TECH. & AGR. DIV.

ABSTRACT

Amounts of soil loss from an unprotected newly constructed backslope were two to four times greater than loss from a comparable slope 5 years after construction. Of six roadside treatments studied, the two showing consistently large amounts of soil loss during the first critical rainy period were the only ones without a straw mulch covering.

In an earlier study,[1] five different mulch and grass-legume applications to a 5-year-old road backslope were equally effective in eliminating erosion. Only the untreated control plots showed appreciable amounts of soil movement during the first year of measurement. At that time, it was hypothesized that erosion rates from freshly constructed backslopes are generally substantially higher. Consequently, such slopes may offer considerably more resistance to stabilization, especially during the critical first year after construction.

The present study was conducted to test this hypothesis, not only to provide information on the stability of new slopes but also to aid in formulating measures to minimize soil loss. Experimental design and treatments are essentially the same as those described in the 1967 report, the principal difference being that these plots were established in the fall following road construction.

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[1] C. T. Dyrness. Grass-legume mixtures for roadside soil stabilization. Pacific Northwest Forest & Range Exp. Sta. USDA Forest Serv. Res. Note PNW-71, 19 pp., illus. 1967.

METHODS

In late August 1967, two blocks of six backslope plots each were established along a road in the Blue River District of the Willamette National Forest. The road, constructed during the early summer of 1967, is at an elevation of 3,100 feet. The soil (Slipout series) is imperfectly drained and exhibits a clay loam surface grading into a silty clay subsoil. Parent material is largely greenish tuffs and breccias.

Five grass-legume mixtures and a control were replicated twice. Plots were 6 feet wide and as long as the backslope--generally about 20 to 25 feet. Species composition and amounts applied of the seed mixtures are shown in table 1. With the exception of the control plots, all plots received a blanket application of ammonium phosphate fertilizer (16-20-0) at the rate of 400 pounds per acre both at the time of seeding (August 1967) and the following April (1968). Treatments were as follows: (1) control--slope left untouched, (2) mulch only--wheat straw mulch applied at the rate of 2 tons per acre, (3) Blue River District mixture--seed at the rate of 25 pounds per acre applied without mulch, (4) Oregon Highway mixture--seed at the rate of 40 pounds per acre and straw mulch at the rate of 2 tons per acre, (5) experimental mixture No. 1--43 pounds per acre of seed and 2 tons per acre of straw mulch, and (6) experimental mixture No. 2--43 pounds per acre of seed and 2 tons per acre of straw mulch.

Soil movement on the plots was evaluated by a slope profile measurement technique.[2] At the time of each measurement, percentage of vegetative cover on each plot was also estimated. Initial slope profile measurements were made soon after plot establishment in September 1967, and subsequent measurements were made in April, June, and September of 1968.

RESULTS AND DISCUSSION

Although these plots were seeded early in the fall, plant growth was rather severely limited prior to and during the cold, wet, winter months. Amounts of grass and legume cover remained relatively low until April. However, only 2 months later, all seeded plots were virtually fully protected by plant cover (table 1). Therefore, the growth of seeded species during the fall and winter months apparently provides insufficient cover for soil stabilization, at least at moderate to high elevations.

Soil losses or gains during the first rainy season following road construction are shown in table 2 in the April column. With the exception of one plot of experimental mix No. 1, where a small slump occurred, the only plots to show consistently large

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[2] See footnote 1.

Table 1.--*Species composition and plant cover on plots representing five treatments during the first year following seeding*

Treatment	Pounds per acre of seed	Species composition	Block	April	June	Sept.
				- - *Total percent plant cover* - -		
Control			1	0	0	5
			2	0	0	15
Mulch and fertilizer			1	5	70	75
			2	5	65	80
Blue River District mixture (no mulch)	6.25	Colonial bentgrass (*Agrostis tenuis* Sibth.)	1	20	95	95
	5.00	Creeping red fescue (*Festuca rubra* L.)	2	10	95	95
	3.75	Perennial ryegrass (*Lolium perenne* L.)				
	8.75	Tall fescue (*Festuca arundinacea* [Schreb.] Wimm.)				
	1.25	White Dutch clover (*Trifolium repens* L.)				
Oregon Highway mixture	18.0	Creeping red fescue	1	25	75	85
	12.0	Chewings fescue (*Festuca rubra* var. *commutata* Gaud.)	2	40	95	95
	4.0	Perennial ryegrass				
	6.0	White Dutch clover				
Experimental mixture No. 1	8.0	Italian ryegrass (*Lolium multiflorum* Lam.)	1	10	95	95
	20.0	Tall fescue	2	35	90	90
	8.0	Creeping red fescue				
	3.0	Colonial bentgrass				
	2.0	New Zealand white clover (*Trifolium repens* L.)				
	2.0	Birdsfoot trefoil (*Lotus corniculatus* L.)				
Experimental mixture No. 2	8.0	Italian ryegrass	1	25	90	90
	20.0	Tall fescue	2	35	95	95
	8.0	Creeping red fescue				
	3.0	Colonial bentgrass				
	3.0	Red clover (*Trifolium pratense* L.)				
	3.0	Alsike clover (*Trifolium hybridum* L.)				
	7.0	'Lana' woollypod vetch (*Vicia dasycarpa* Ten.)				

Table 2.--*Average cumulative soil loss or gain on 12 backslope plots during the first year after construction, compared with soil movement in 1 year on a comparable backslope 5 years after construction*

Treatment and block	1968			1-year results from 5-year-old backslope[1]
	April	June	Sept.	
	Inches			
Control:				
1	-0.48	-0.55	-0.83	-0.23
2	-.45	-.59	-.84	-.44
Mulch only:				
1	-.06	-.08	+.05	+.13
2	--	-.07	-.07	-.14
Blue River District mixture:				
1	-.72	-.72	-.77	+.05
2	-.42	-.55	-.31	+.14
Oregon Highway mixture:				
1	-.12	-.13	-.20	-.13
2	-.11	-.19	-.23	-.04
Experimental mixture No. 1:				
1	[2]-.54	-.66	-.65	+.11
2	+.10	+.14	+.17	+.10
Experimental mixture No. 2:				
1	+.01	-.07	-.07	+.14
2	+.02	+.08	+.11	-.01

[1] Data taken from C. T. Dyrness. Grass-legume mixtures for roadside soil stabilization. Pacific Northwest Forest & Range Exp. Sta. USDA Forest Serv. Res. Note PNW-71, 19 pp., illus. 1967.

[2] Most of this movement was caused by a small slump near the base of the plot.

amounts of soil loss were the control and Blue River District mixture plots. It is significant that these two treatments are the only ones which lacked a straw mulch covering. In order to fully appreciate the magnitude of soil loss, one needs only to realize that 1 inch of soil is roughly equivalent to 100 tons per acre. Thus, a 0.45-inch loss represents a soil loss of approximately 45 tons on an acre basis. Although much of this eroded material comes to rest in the roadside ditch, road drainage water during rainy periods generally carries some of the sediment into stream channels. The soil gain figures shown in the table probably represent deposition of soil which raveled down from the top of the backslope on the measured slope section.

By June and September, a nearly complete covering of grasses and legumes on all plots, including plots treated with the Blue River District mixture (table 1), had substantially reduced soil movement. As a result, the control plots were the only ones to show continued high rates of soil loss during this period (table 2). It is interesting to note that for the control plots dry season loss by raveling was almost as great as rain-caused soil loss.

The hypothesized greater instability of freshly constructed backslopes is apparently borne out by the data in table 2. One-year soil losses from unprotected new slopes are roughly two to four times greater than losses in a 1-year period from a 5-year-old backslope. However, since soil and slope characteristics of the two sites differ, sweeping general conclusions should be avoided.

CONCLUSIONS

Considerable evidence has indicated the desirability of treating newly constructed roadside slopes in the early fall before heavy rains. Probably most important is that the loose, unprotected soil is most vulnerable to erosion during this period and, therefore, needs protection. For example, Fredriksen[3] reported that stream sediment content increased 250 times during the first rainstorms after road construction in a small drainage in the western Cascades. The open, porous soils on freshly constructed slopes offer a very favorable seedbed. On the other hand, slopes which have been exposed to the beating action of rainfall tend to have smooth, sealed surfaces and are less favorable for germination and seedling establishment.

Results of this study suggest that mulching backslopes may be essential for reducing soil loss to a minimum during the first few critical months following construction. The only mulched plot which showed a large amount of soil movement did so as a result of a rather deep-seated slump--indicating, of course, that these treatments are effective only in curtailing surface erosion. These results also indicate that, contrary to appearances, a luxuriant growth of grass and legumes during the first growing season following fall treatment is not conclusive evidence that soil loss was negligible during the preceding winter months.

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[3] R. L. Fredricksen [Fredriksen]. Sedimentation after logging road construction in a small western Oregon watershed. U.S. Dep. Agr. Misc. Pub. 970, 56-59, illus. 1965.

Pacific Northwest Forest and Range Experiment Station

DA Forest Service **RESEARCH NOTE**

PNW–124

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Effect of Zectran on Microbial Activity in a Forest Soil

OCT 26 1970
TECH. & AGR. DIV.

by

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and

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ABSTRACT

When Zectran or No. 2 fuel oil was applied to soil in concentrations far greater than those that could result from current operational application rates, neither material adversely affected soil microbial activity. We conclude from these data that low-volume applications of Zectran as an insecticide for forest use poses no hazard to soil microbes.

The insecticide Zectran[1/] applied aerially at a nominal rate of 0.15 pound per acre was as effective as malathion or DDT applied at 1.0 pound per acre to control western spruce budworm (*Choristoneura occidentalis* Freeman) in Montana field tests (Buffam, Meyer, and Miskus 1967). On ponderosa pine foliage in the laboratory, Zectran proved more toxic than DDT against larvae of a pine tussock moth (*Dasychira* sp.) (Lyon, Brown, and Richmond 1967).

The chemical nature of Zectran suggests it may be much less persistent in the forest ecosystem than DDT (Hammer 1962). Zectran levels in plant foliage decrease rapidly after application (Pieper and Miskus 1967). Thus, it is a promising chemical for use against forest tree defoliators previously controlled by aerial applications of DDT (Anonymous 1967).

In determining the safety of chemicals proposed for use in the forest environment, we are interested in effects of the chemicals on soil microbes which influence soil fertility. Soil respiration, as indicated by carbon dioxide (CO_2) evolution, is a good general index of the activity of microflora involved in organic matter decomposition (Casida 1968). This index was used in our laboratory experiments to measure effects of Zectran on the microflora found in a coastal Oregon forest soil. (See details in table 1 and "Materials and Methods.")

Zectran applied to soil without tree litter or oil carrier had no apparent effect on CO_2 evolution (table 1). Tree litter applied to soil without Zectran or oil carrier also had no apparent effect (table 2). Further, there appeared to be no interaction between Zectran and tree litter (table 3).

[1/] The Dow Chemical Company trademark for 4-dimethylamino-3, 5-xylyl methylcarbamate.

Mention of companies or products does not constitute an endorsement by the Forest Service or the U. S. Department of Agriculture.

Table 1.--*Effect of Zectran on evolution of CO_2 for 70 days from Astoria silty clay loam*

Soil treatment comparisons	Total CO_2 as carbon	Difference[1]
	---------Milligrams	*---------*
1. No treatment	111	
vs.		
Zectran at 1 p.p.m.	107	4
2. No treatment	111	
vs.		
Zectran at 10 p.p.m.	104	7
3. Zectran at 1 p.p.m.	107	
vs.		
Zectran at 10 p.p.m.	104	3

[1] First two comparisons not included in tests of significance; difference in third comparison is not significant at the 95-percent level of probability.

Table 2.--*Effect of tree litter on evolution of CO_2 for 70 days from Astoria silty clay loam*

Soil treatment comparisons	Total CO_2 as carbon	Difference[1]
	---------Milligrams	*--------*
1. No treatment	111	
vs. alder litter	105	6
2. No treatment	111	
vs. conifer litter	122	11
3. All treatments with alder litter	153	
vs. all treatments with conifer litter	159	6
4. All treatments without litter	148	
vs. all treatments with litter	156	8

[1] First two comparisons not included in tests of significance; differences in third and fourth comparisons are not significant at the 95-percent level of probability.

Table 3.--*Effect of Zectran in combination with tree litter on evolution of* CO_2 *for 70 days from Astoria silty clay loam*

Soil treatment comparisons	Total CO_2 as carbon	Difference[1]
	Milligrams	*Milligrams*
1. Zectran at 1 p.p.m. + alder litter	110	
vs.		
Zectran at 10 p.p.m. + alder litter	96	14
2. Zectran at 1 p.p.m. + conifer litter	100	
vs.		
Zectran at 10 p.p.m. + conifer litter	113	13

[1] Differences were not significant at the 95-percent level of probability.

Comparisons based on means of all treatments combined (table 2) indicate that mean CO_2 evolution for all treatments combined is substantially higher than means of treatments which included only Zectran or tree litter. Thus, the oil carrier is indicated as having some role in increasing microbial respiration. The comparisons shown in table 4 demonstrate that the carrier indeed is responsible for a substantial increase in microbial respiration. There was no significant difference in CO_2 production between the rates of carrier used, but means of all treatments containing the carrier were significantly greater than means of all treatments that did not include the carrier.

We next looked for interactions between Zectran and the carrier. The CO_2 index was not significantly different between Zectran in carrier at 1 part per million (p.p.m.) and at 10 p.p.m. (table 5). We do see, however, that when Zectran in carrier is compared with the carrier only, presence of Zectran apparently causes a significant decrease in CO_2 evolution. While this decrease is significant relative to levels obtained with carrier only, the absolute value for CO_2 production is still substantially higher than values measured in the absence of any carrier.

In our study of interactions between the carrier and tree litter (table 6), there was no significant difference between carrier rates of 1 and 10 p.p.m. in combination with conifer litter. However, when alder litter and carrier were together, the 10-p.p.m. carrier rate led to a highly significant reduction

Table 4.--*Effect of acetone-fuel oil carrier on evolution of CO_2 for 70 days from Astoria silty clay loam*

Soil treatment comparisons	Total CO_2 as carbon	Difference[1]
	Milligrams	
1. No treatment	111	
vs. carrier at 1-p.p.m. rate[2]	183	72
2. No treatment	111	
vs. carrier at 10-p.p.m. rate	192	81
3. Carrier at 1-p.p.m. rate	183	
vs. carrier at 10-p.p.m. rate	192	9
4. All treatments without carrier	106	
vs. all treatments with carrier	194	88**

[1] First two comparisons not included in tests of significance; difference marked ** is significant at the 99-percent level of probability.

[2] Carrier rates of 1 and 10 p.p.m. are equal to those used when Zectran at 1 and 10 p.p.m. was dissolved in carrier.

Table 5.--*Effect of Zectran in combination with acetone-fuel oil carrier on evolution of CO_2 for 70 days from Astoria silty clay loam*

Soil treatment comparisons	Total CO_2 as carbon	Difference[1]
	Milligrams	
1. Zectran at 1 and 10 p.p.m. + carrier	169	
vs.		
carrier only at 1- and 10-p.p.m. rates[2]	188	19*
2. Zectran at 1 p.p.m. + carrier	167	
vs.		
Zectran at 10 p.p.m. + carrier	170	3

[1] Difference marked * is significant at the 95-percent level of probability.

[2] Carrier rates of 1 and 10 p.p.m. are equal to those used when Zectran at 1 and 10 p.p.m. was dissolved in carrier.

Table 6.--*Effect of acetone-fuel oil carrier in combination with tree litter on evolution of CO_2 for 70 days from Astoria silty clay loam*

Soil treatment comparisons	Total CO_2 as carbon	Difference[1]
	Milligrams	
1. Carrier at 1-p.p.m. rate + conifer litter	187	
vs.		
carrier at 10-p.p.m. rate + conifer litter	197	10
2. Carrier at 1-p.p.m. rate[2] + alder litter	201	
vs.		
carrier at 10-p.p.m. rate + alder litter	170	31**

[1] Difference marked ** is significant at the 99-percent level of probability.

[2] Carrier rates of 1 and 10 p.p.m. are equal to those used when Zectran at 1 and 10 p.p.m. was dissolved in carrier.

in CO_2 evolution. Red alder litter has a high content of phenolic compounds, some of which are inhibitory to micro-organisms (Li et al. 1969). We hypothesize that the higher rate of acetone-fuel oil carrier released phenolic compounds from the alder litter and that some inhibition of microbial activity thus resulted. Again, the reduction we noted as a result of this interaction appears not to be substantial in comparison with CO_2 evolution rates from all treatments that did not contain the carrier.

When we looked for interactions between all three treatments used in this study--Zectran, litter, and carrier--we found no significant difference between Zectran in carrier at 1 p.p.m. versus 10 p.p.m. in the presence either of alder or conifer litter (table 7).

Finally, in determining the relative effect of acetone and of fuel oil in the carrier mixture, we found no significant differences between untreated controls and fuel oil at either the 1- or 10-p.p.m. rate; nor was there any difference between fuel oil alone at 1- versus 10-p.p.m. rates (table 8). In contrast, presence of acetone at the 1-p.p.m. rate significantly increased CO_2 evolution over that measured from untreated soil. Acetone at the 10-p.p.m. rate also significantly increased CO_2 evolution, but the absolute amount of increase was substantially less than that noted with the 1-p.p.m.

Table 7.--*Effect of Zectran, tree litter, and acetone-fuel oil carrier on evolution of CO_2 for 70 days from Astoria silty clay loam*

Soil treatment comparisons	Total CO_2 as carbon	Difference[1]
	----------*Milligrams*----------	
1. Zectran at 1 p.p.m. + alder litter + carrier	187	
vs.		
Zectran at 10 p.p.m. + alder litter + carrier	202	15
2. Zectran at 1 p.p.m. + conifer litter + carrier	200	
vs.		
Zectran at 10 p.p.m. + conifer litter + carrier	193	7

[1] Differences not significant at 95-percent level of probability.

Table 8.--*Effect of fuel oil and of acetone on evolution of CO_2 for 70 days from Astoria silty clay loam*[1]

Soil treatment comparisons[2]	Total CO_2 as carbon	Difference[3]
	---------*Milligrams*---------	
1. Soil alone	81	
vs. fuel oil at 1-p.p.m. rate	78	3
2. Soil alone	81	
vs. fuel oil at 10-p.p.m. rate	84	3
3. Fuel oil at 1-p.p.m. rate	78	
vs. fuel oil at 10-p.p.m. rate	84	6
4. Soil alone	81	
vs. acetone at 1-p.p.m. rate	166	85*
5. Soil alone	91	
vs. acetone at 10-p.p.m. rate	121	40*
6. Acetone at 1-p.p.m. rate	166	
vs. acetone at 10-p.p.m. rate	121	45*

[1] These data are from a separate study. Soil age after collection and environmental temperature were different from that in the main study, accounting for the generally lower absolute values for total CO_2 as carbon.

[2] Rates are equal to those used for acetone-oil carrier in Zectran treatments at 1 and 10 p.p.m..

[3] Differences marked * are significant at the 95-percent level of probability.

rate. We conclude from these comparisons that acetone, not fuel oil, was responsible for increases in CO_2 evolution noted whenever the acetone-fuel oil carrier was included in treatments.

Thus, when Zectran or No. 2 fuel oil was applied to soil in concentrations far greater than those that could result from current operational application rates (Buffam, Meyer, and Miskus 1967), neither material adversely affected soil microbial activity. We conclude from these data that low-volume applications of Zectran as an insecticide for forest use poses no hazard to soil microbes.

MATERIALS AND METHODS

In general, an Astoria silty clay loam soil was subjected to different treatments which included Zectran, forest tree litter, and an acetone-oil carrier mixture (table 9). Treated soil was incubated for 70 days, and microbial activity was determined from the amount of CO_2 evolved.

A bulk sample of the A11 horizon of Astoria silty clay loam was taken beneath a conifer stand--Douglas-fir *(Pseudotsuga menziesii),* western hemlock *(Tsuga heterophylla),* and Sitka spruce *(Picea sitchensis)*--at the Cascade Head Experimental Forest near Otis, Oreg. A detailed list of chemical and physical properties of this soil is included in Franklin et al. (1968). For the soil used in the present study, organic matter was 28 percent, total carbon by dry combustion was 16 percent, and Kjeldahl nitrogen was 0.41 percent.

Fifty-gram portions of sieved (10-mesh) soil, ovendry basis, were transferred into 250-milliliter widemouth Erlenmeyer flasks. Each treatment (table 9) was replicated three times. In treatments which contained forest litter or Zectran powder, these additives were mixed with the soil before it was transferred to the flasks. Distilled water was then added in sufficient amounts to bring moisture content of the treated soil to 50 percent of water-holding capacity (81 percent, dry weight basis).

For treatments which included Zectran in an oil carrier, a stock solution was prepared by dissolving 2 grams of the insecticide in 20 milliliters acetone, then adding 80 milliliters No. 2 fuel oil. Subsequent dilutions were made so that 1 milliliter additions of the solution to 50 grams of soil would yield 1 or 10 p.p.m. actual Zectran. Treatments which included the carrier alone or carrier in combination with litter were in amounts of the carrier equivalent to those in which Zectran had been included.

The tree litter used was collected from the Cascade Head Experimental Forest near where the soil was collected for the study. Litter was air dried

Table 9.--*Description of treatments to Astoria silty clay loam and total CO_2 evolved over 70 days of incubation*

Soil treatment[1/]	Total CO_2 as carbon
	Milligrams
None--control	111
Z1	107
Z1, conifer	100
Z1, alder	110
Z10	104
Z10, conifer	113
Z10, alder	96
Conifer	122
Alder	105
Z1, oil	167
Z1, oil, conifer	200
Z1, oil, alder	187
Z10, oil	170
Z10, oil, conifer	193
Z10, oil, alder	202
Oil(1)	183
Oil(10)	192
Oil(1), conifer	187
Oil(10), conifer	197
Oil(1), alder	201
Oil(10), alder	170

[1/] Z1 or Z10 = Zectran at 1 or 10 p.p.m.; conifer or alder = type of forest litter; oil(1) or oil(10) = oil without Zectran but in same amount as used when Zectran in oil carrier was at 1 or 10 p.p.m. Oil carrier was a 1:4 mixture of acetone and No. 2 fuel oil.

at room temperature and ground to pass through a 60-mesh sieve. The alder litter contained 51.74 percent carbon and 2.31 percent nitrogen; the conifer litter, 51.85 percent carbon and 0.84 percent nitrogen.

Each flask containing soil and additives was connected to a CO_2-free, water-saturated air supply. The exit connection from the flask was inserted into a tube containing 1N NaOH to absorb CO_2 evolved from the soil by microbial activity. The entire respiration setup was incubated at $25^{\circ} \pm 1^{\circ}$ C. for 70 days. The tubes of NaOH were replaced at intervals of 1, 4, 8, 14, 28, 42, and 70 days. Amount of CO_2 absorbed by the NaOH was determined by double titration on a Beckman automatic titrator. Details of the apparatus and methods are given in Bollen and Lu (1961) and Bollen and Glennie (1961).

Resulting data were subjected to two analyses of variance in which treatment degrees of freedom were partitioned into an orthogonal set of comparisons (tables 1-8).

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PNW-125 *August 1970*

PERIODIC VARIATION IN PHYSICAL AND CHEMICAL PROPERTIES OF TWO CENTRAL WASHINGTON SOILS

by

Tom D. Anderson, *Chemist*

and

Arthur R. Tiedemann, *Range Scientist*

ABSTRACT

Soils derived from two widely distributed parent materials in central Washington were examined periodically during 1968-69 for physical and chemical properties. Basalt soils showed significant periodic variation in cation exchange capacity, pH, and Na and K contents. In sandstone soils, cation exchange capacity and Ca, Na, and K contents varied significantly among sampling dates. Although certain physical properties showed definite trends, none were statistically significant.

These results indicate that, where sampling dates vary, periodic variation in certain chemical properties of these soils may be a confounding factor in evaluating research findings or management prescriptions.

INTRODUCTION

Physical and chemical properties of soils are often used to evaluate the effect of research treatments or the impact of management prescriptions on the microenvironment of wildland areas. For example, changes in physical and chemical properties have been used to evaluate the effect of grazing animals on the soil (Reed and Peterson 1961; Linnartz, Hse, and Duvall 1966; and Laycock and Conrad 1967). Physical properties have also been used to indicate the effect of prescribed burning (Tarrant 1956) and to compare the effect of two different types of logging on the soil (Dyrness 1967). In addition, chemical properties have been studied (Isaac and Hopkins 1937) as an indicator of the effect of logging and burning on the soil. When samples comparing one treatment or prescription with another one are taken at different points in time, periodic variation in physical and chemical properties of the soil may be a confounding factor.

This study was conducted to determine if periodic variation in these properties exists and is significant in two central Washington soils.

METHODS

Two homogeneous soil areas of approximately 1 acre were selected on representative, well-vegetated soil derived from sandstone and basalt--two parent materials common to central Washington (Wooldridge 1964). The basalt area, located near Blewett Pass in Washington, was situated on a north-facing slope at approximately 6,000-foot elevation (fig. 1). The dense overstory consisted of subalpine fir *(Abies lasiocarpa)*, Engelmann spruce *(Picea engelmannii)*, and lodgepole pine *(Pinus contorta)*. The understory was a sparse cover of grouse whortleberry *(Vaccinium scoparium)*. The soil contained approximately 46 percent sand, 45 percent silt, and 9 percent clay. The litter layer was 3 to 4 inches deep.

The sandstone site was located near Leavenworth, Wash., on a NNE slope at an elevation of 2,600 feet (fig. 2). The overstory consisted of grand fir *(Abies grandis)* and Douglas-fir *(Pseudotsuga menziesii)*, whereas the sparse understory was comprised of elk sedge *(Carex geyeri)*, Oregon grape (*Mahonia* spp.), and snowberry (*Symphoricarpos* spp.). The soil consisted of approximately 64 percent sand, 25 percent silt, and 11 percent clay, and the litter layer was from 1 to 2 inches deep.

Each site was divided graphically into milacre plots from which six were randomly selected for sampling. These 6- by 7-foot plots served as sample locations (replications) for the entire period of study. On any one sampling occasion, a random 1-square-foot area on each of the six milacre plots was sampled. Sampling was started in late May of 1968 on the sandstone site and early June on the basalt site and was continued periodically until mid-August. Final samples were taken in June 1969. Three cores were taken at each of the six milacre locations on each date for physical analysis of porosity

Figure 1.--*Study site on basalt parent material.*

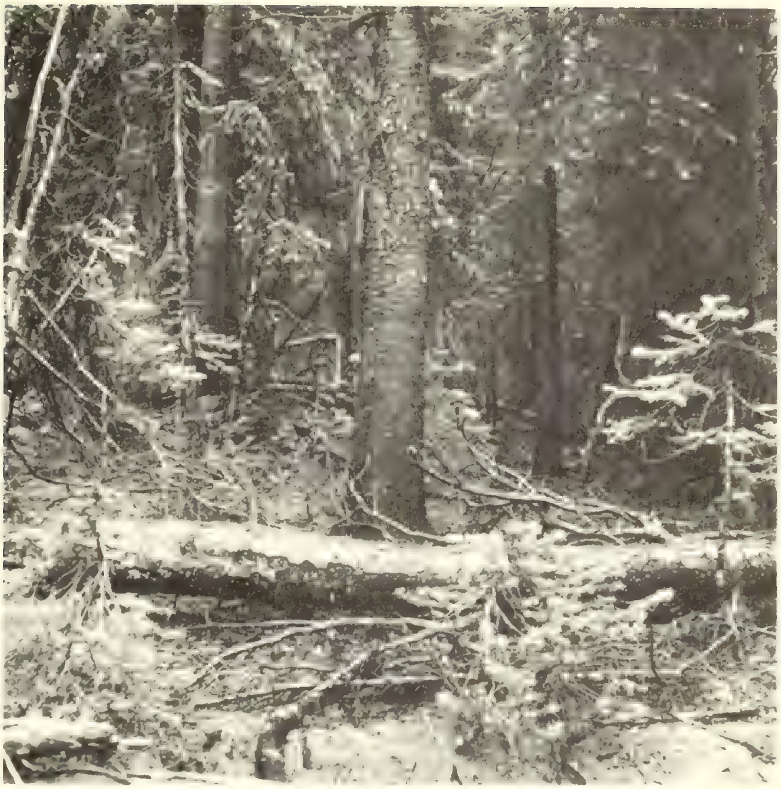
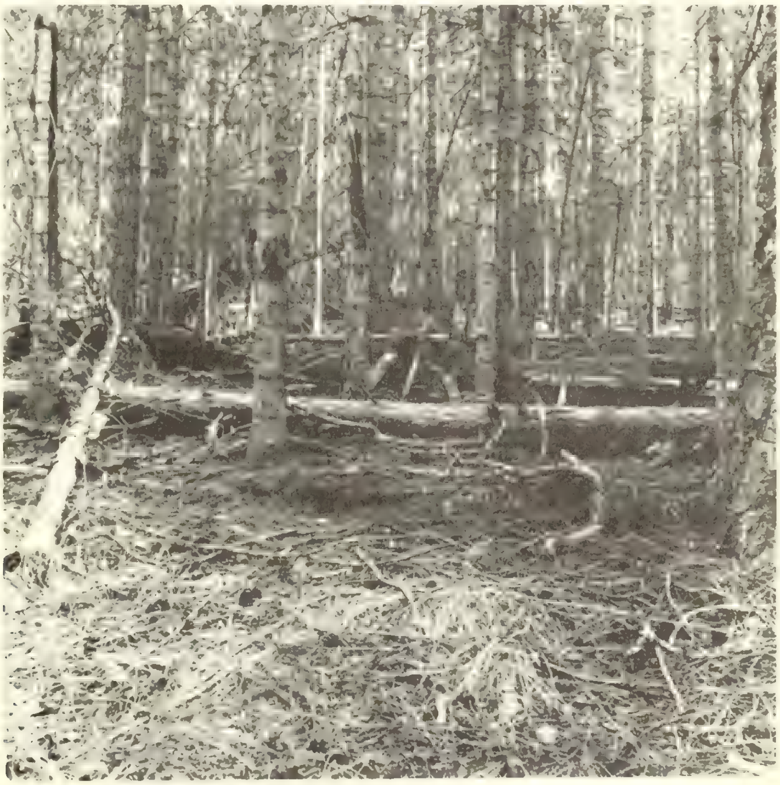


Figure 2.--*Study site on sandstone parent material.*



by the air pycnometer method (Wooldridge 1968) and bulk density (Black *et al.* 1965). One loose sample was taken on each of the six milacre plots on each date for determination of moisture content and for analysis of chemical properties. These properties included: pH in a 1 to 2.5 water suspension measured by glass electrode pH meter (Jackson 1958); total nitrogen using a Coleman analyzer (Keeney and Bremner 1967); organic matter by Walkley-Black wet digestion method (Jackson 1958); cation exchange capacity by the ammonium acetate method using acidified sodium chloride (Chapman and Pratt 1961) with iodometric titration of ammonia in the sodium chloride extract (Ballentine and Gregg 1947); exchangeable Ca, Mg, Mn, Na, and K by atomic absorption using a 1-percent lanthanum chloride solution of the extract from the cation exchange capacity determination; and available P by bicarbonate extraction (Chapman and Pratt 1961) with ascorbic acid substituted for stannous chloride. All determinations were done in duplicate.

Data were evaluated by analysis of variance using a completely randomized design.

RESULTS AND DISCUSSION

In soil derived from basalt parent material, both physical and chemical properties fluctuated throughout the sampling period. However, only pH, cation exchange capacity, Na, and K varied significantly ($P = 0.05$) among dates (table 1). At the 10-percent level of testing, organic matter, Ca, and Mg were also significant. The extreme fluctuation in organic matter content appears to be unrealistic. Detection of significant differences among dates may have resulted from bias in the sampling procedure or a type I error in the statistical interpretation of the data.

In addition to significant variation among dates, there were trends in the data which indicate that the chemical properties were interrelated. Organic matter, cation exchange capacity, N, Ca, K, Mg, and Mn all showed distinct peaks on July 8, 1968. The peak in cation exchange capacity and N on this date probably resulted from the increase in organic matter. Similarly, peaks in exchangeable cations were likely the result of the increased cation exchange capacity on July 8. None of these changes appeared to be related to soil reaction or moisture content.

Variations in porosity and bulk density were not significant. However, the declining trend for porosity from June 1968 to August 1968 was probably the result of the decline in soil moisture and shrinking of the soil upon drying.

Soils derived from sandstone parent material showed significant differences ($P = 0.05$) in cation exchange capacity, N, Ca, Na, and K among dates

Table 1.--*Variation in physical and chemical properties of soil derived from basalt parent material on seven sampling dates*

Sampling date	Porosity	Bulk density	Organic matter	N	Cation exchange capacity	Exchangeable					Avail-able P	pH	Moisture content
						Na	K	Ca	Mg	Mn			
	Percent	*g./cm.*^{3}	--*Percent*--		--*Milliequivalent/100 g.*--						*p.p.m.*		*Percent*
June 10, 1968	77.6	0.61	10.61	0.257	29.71	0.183	0.441	1.37	0.173	0.034	14.16	4.85	--
June 24, 1968	76.4	.64	12.11	.292	32.74	.194	.424	1.72	.207	.029	13.73	4.80	67.67
July 8, 1968	75.1	.61	14.73	.305	37.20	.176	.481	2.47	.247	.046	15.45	4.81	43.64
July 22, 1968	74.3	.59	9.84	.246	27.49	.173	.322	1.23	.116	.026	11.95	5.02	36.49
Aug. 5, 1968	75.0	.59	10.66	.261	29.00	.165	.375	1.10	.147	.028	12.25	5.06	29.26
Aug. 20, 1968	72.8	.65	10.97	.237	29.16	.135	.340	1.28	.141	.022	14.54	5.06	41.31
June 26, 1969	75.6	.64	14.42	.252	44.15	.160	.322	1.79	.243	.043	16.16	5.29	71.89
Mean	75.3	.62	11.91	.264	32.80	.169	.386	1.57	.182	.032	14.10	4.98	--
Coefficient of variation in percent	4	14	27	32	22	6	25	53	46	62	24	4	--
F test			†		**	**	*	†	†			*	

** Significant at P = 0.01.
* Significant at P = 0.05.
† Significant at P = 0.10.

(table 2). In addition, Mg varied significantly at the 10-percent level of testing. As in the basalt soil, cation exchange capacity and N trends followed organic matter fluctuations. However, exchangeable cations in the sandstone soil did not appear to be as strongly related to cation exchange capacity as in the basalt soil. Calcium, Mg, Mn, and K all showed a peak on July 8, 1968--the same date a peak in cation exchange capacity occurred. Of these, only Ca and Mn followed the decline in cation exchange capacity to the August 1968 sampling date.

Although not significant, the variation in porosity of sandstone appears to follow the trend of organic matter. Apparently, organic matter regulates porosity in the sandstone soil to some extent. The fluctuation in bulk density showed an inverse relationship to organic matter and porosity.

In addition to significant periodic variation, most of the physical and chemical properties in both soils were at a different level on the June 1969 sampling date than on June 10, 1968. This is probably the result of a different sequence of climatic events in the 2 years.

CONCLUSIONS

The significant periodic variation in chemical properties of these two soils is likely to be a confounding factor when these properties are used to interpret results of research treatments or management prescriptions. In addition, when interpretations are based on samples collected on the same date in different years, confounding is even more likely.

Since meteorological data were not taken, it was not possible to relate changes observed in this study to rainfall or air temperature.

The results may suggest a need to relate climatic and microclimatic characteristics to periodic variations in physical and chemical properties of the soil.

Table 2.--*Variation in physical and chemical properties of soil derived from sandstone parent material on seven sampling dates*

Sampling date	Porosity	Bulk density	Organic matter	N	Cation exchange capacity	Exchangeable					Avail-able P	pH	Moisture content
						Na	K	Ca	Mg	Mn			
	Percent	*g./cm.*^{3}	---*Percent*---		---------------*Milliequivalent/100 g.*-------------						*p.p.m.*		*Percent*
May 27, 1968	57.5	1.06	3.70	0.102	15.74	0.190	0.666	8.31	1.00	0.062	71.70	5.92	23.47
June 10, 1968	60.7	1.03	3.80	.101	14.81	.187	.532	8.53	.92	.047	64.62	6.10	24.29
June 24, 1968	62.6	1.01	3.42	.079	13.31	.318	.671	6.62	.91	.050	77.79	5.62	11.47
July 8, 1968	61.8	1.01	3.76	.083	14.09	.227	.725	7.97	.99	.061	74.99	5.81	8.87
July 22, 1968	61.6	1.00	3.25	.073	12.61	.194	.665	6.76	.81	.050	75.83	5.90	6.71
Aug. 20, 1968	59.2	1.04	2.89	.074	12.78	.118	.820	6.85	1.00	.034	76.27	5.71	17.19
June 3, 1969	59.0	1.09	3.13	.071	15.40	.136	.592	7.42	.95	.028	74.44	6.25	12.41
Mean	60.3	1.03	3.42	.083	14.10	.196	.667	7.49	.94	.047	73.52	5.90	--
Coefficient of variation in percent	5	8	20	17	10	17	13	16	12	51	42	7	--
F test				**	**	**	**	*	†				

** Significant at P = 0.01.
* Significant at P = 0.05.
† Significant at P = 0.10.

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RELATIONSHIP OF NEEDLE SURFACE AREA TO NEEDLE VOLUME IN PONDEROSA PINE AND LODGEPOLE PINE

by

William Lopushinsky, *Principal Plant Physiologist*

ABSTRACT

The relationship of needle surface area to needle volume for ponderosa and lodgepole pine seedlings is presented.

It is usually desirable to express rates of photosynthesis or transpiration on a common base such as leaf surface area. Direct measurement of leaf surface area in conifers is difficult; consequently, needle surface area often is estimated by relating it to a more easily measured characteristic such as weight or volume of needles.[1] [2] Clark[3] expressed rate of photosynthesis on the basis of leaf volume, and a simple volumeter for estimating quantity of conifer foliage has been described by Ronco.[4/]

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[1] D. R. Cable. Estimating surface area of ponderosa pine foliage in central Arizona. Forest Sci. 4: 45-49. 1958.

[2] T. T. Kozlowski and F. X. Schumacher. Estimation of stomated foliar surface area of pines. Plant Physiol. 18: 122-127. 1943.

[3] J. Clark. Photosynthesis and respiration in white spruce and balsam fir. Tech. Pub. 85, 72 pp. State Coll. Forest., Syracuse, N. Y. 1943.

This paper shows the relationship between surface area and volume for individual needles of seedlings of ponderosa pine (*Pinus ponderosa* Laws.) and lodgepole pine (*Pinus contorta* Dougl.).

Material and Methods

Eighty needles that varied in length were taken from terminal and lateral shoots of potted 3-year-old seedlings growing in a greenhouse. Only one needle from a fascicle was taken. Needles were immersed in water overnight to assure maximum turgidity at the time of measurement.

In ponderosa pine, a fascicle consists of three needles which form a cylinder. In cross section, each needle has two flat radial faces and one curved outer face representing one-third of the circumference of a circle. The average width of the radial surface of each needle was determined by measuring the widths of both radial surfaces at three equally spaced locations along the length of the needle with a low-power binocular microscope.

In lodgepole pine, a fascicle consists of two needles which form a cylinder. Each needle has one flat diametrical face and one curved outer face representing one-half of the circumference of a circle. The average width of the diametrical surface was determined from measurements taken at three equally spaced locations along the needle. In both species, needle lengths were measured to a point a short distance from the needle tip to compensate for taper at the tip. Needle surface areas were calculated according to the equations:

$$\begin{aligned} S &= 1/3\ C1 + r_1 1_1 + r_2 1_2 \\ &= 4.09\ r1 \text{ (ponderosa pine)} \end{aligned}$$

$$\begin{aligned} S &= 1/2\ C1 + d1 \\ &= 2.57\ d1 \text{ (lodgepole pine)} \end{aligned}$$

where S, C, r, d, and 1 represent surface area ($mm.^2$), circumference,

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[4/] F. Ronco. Volumeter for estimating quantity of conifer foliage. Rocky Mountain Forest and Range Exp. Sta., USDA Forest Serv. Res. Note RM-133. 1969.

radius, diameter, and length, respectively. $R_1 l_1$ and $r_2 l_2$ refer to the dimensions of the two radial surfaces of a ponderosa pine needle.

After the measurement of needle dimensions, each needle was placed in a volumeter, similar to the one described by Clark (see footnote 3), and needle volume was determined by water displacement. Displacement was measured in a pipette graduated to 0.001 milliliter and interpolated to the nearest 0.0005 milliliter. A small amount of Aqua-Gro[5] was added to facilitate wetting the needle and glass surfaces.

The accuracy of the volumeter was checked by measuring small stainless steel rods of known volume, and it was found that the volumeter underestimated true rod volumes by 0.5 to 1.3 percent, depending on the size of the rods. Values for needle volume were corrected accordingly. To minimize effects of temperature on volume changes, the reservoir of the volumeter was jacketed with a piece of Tygon tubing and all measurements were made in a laboratory at a constant temperature.

Results and Discussion

The relationship between needle surface area and needle volume is shown in Figure 1. A T-distribution test showed the regression coefficient

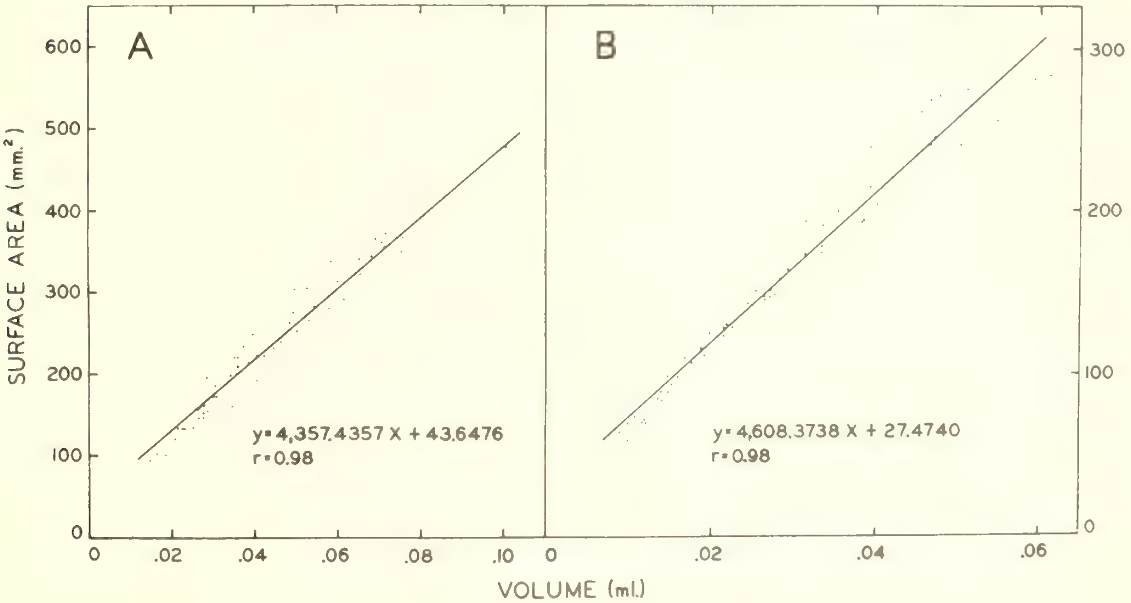

Figure 1.--*Relationship of needle surface area to needle volume for single needles of ponderosa pine (A) and lodgepole pine (B).*

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[5] Mention of products by name does not represent endorsement by the U.S. Department of Agriculture.

to be highly significant. There appears to be a change in slope of the curves below a needle volume of 0.03 milliliter in ponderosa pine and 0.015 milliliter in lodgepole pine, probably a result of a changing relationship of surface area to volume in very short needles.

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PNW-127 *August 1970*

LOG PRICES IN WESTERN WASHINGTON AND NORTHWEST OREGON, 1963-68[1/]

by

Thomas C. Adams, *Economist*

FEB 1 1971
TECH & REF.

ABSTRACT

An annual series of log prices is shown for seven principal species in western Washington and northwest Oregon. The average reported log price rose 60.3 percent between 1963 and 1968. Much of this increase is accounted for by log exports and the trend toward more value added in sorting and other handling as the mixture of log species, sizes, and grades are channeled to different outlets. Prices for export logs rose considerably more than for other logs.

Average annual log prices from 1963 to 1968 are presented by log grade for seven principal species in tables 1-8. These species include Douglas-fir, western hemlock, noble fir, white fir, western redcedar, Sitka spruce, and western white pine.

Prices are shown for water and inland sales combined and for export sales (sales for export outside the United States). Water sales are those in market areas on towable waters, not identified for export.

[1/] This report is based on data from quarterly "Composite Log Sales Analysis" reports published by the Industrial Forestry Association, Portland, Oregon, and is made available with their permission. For 1968, the logs covered by these reports represented approximately 24 percent of the total log harvest from all ownerships in western Washington and the seven northwest Oregon counties.

Inland sales are those in market areas not on towable waters and not identified for export.

General Price Trends

Log prices in western Washington and northwest Oregon rose steadily between 1963 and 1968. The average log price in transactions reported to the Industrial Forestry Association in the Puget Sound, Grays Harbor, and Columbia River Districts was $55.40 per thousand board feet, Scribner scale, in 1963[2] and $88.80 in 1968, an increase of 60.3 percent.

For comparison, the U.S. Bureau of Labor Statistics' wholesale lumber price index for the same period rose 28.6 percent, and the wholesale price index for all commodities rose 8.4 percent.

Prices by Species and Log Grade

The average price of No. 3 Douglas-fir peeler logs, the most common peeler grade, increased 29.7 percent during the period 1963-68 for water and inland sales, from $83.90 to $108.80 per thousand board feet, Scribner scale (fig. 1). The average price for export sales of this grade increased 25.2 percent, from $88.80 to $111.20 per thousand board feet.

The average price of No. 2 Douglas-fir saw logs for water and inland sales increased 27.8 percent during the same period, from $61.90 to $79.10 per thousand board feet; for export sales, the corresponding increase was 40.5 percent, from $69.70 to $97.90.

Western hemlock makes up the second highest volume of log harvest in this region and is the highest volume log export species. The average price of No. 2 western hemlock saw logs rose 38.1 percent during 1963-68 in water and inland sales, from $47.50 to $65.60 per thousand board feet. In export sales, the price rise was 59.7 percent, from $60.10 to $96.

The greatest percentage increase in log prices occurred for Sitka spruce and noble fir, which increased 94.9 and 90.1 percent, respectively, between 1963 and 1968 (all grades, water, inland, and export combined).

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[2] Data for 1963 are available for the third and fourth quarters only.

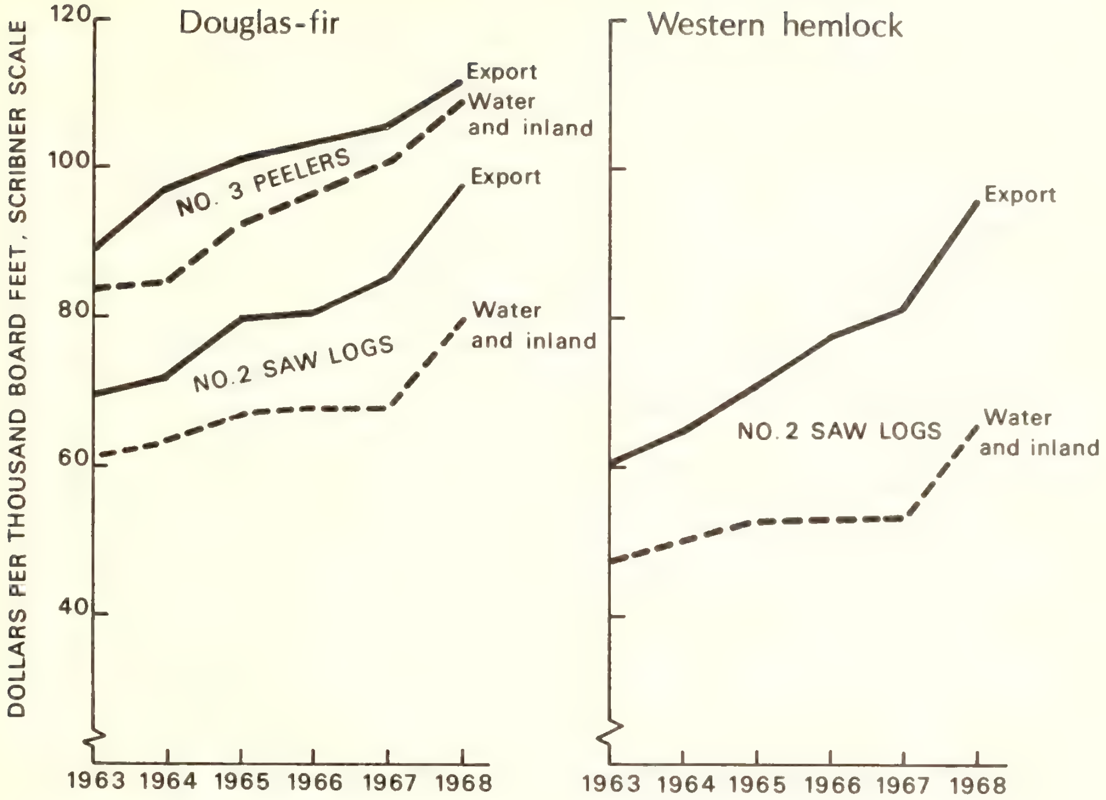

Figure 1.--Average prices for Douglas-fir and western hemlock logs in export sales, and in water and inland sales, for selected grades, 1963-68.

Kinds of Log Markets

Many of the logs harvested annually in western Washington and western Oregon are bought and sold in an open log market[3] before being put to use. These transactions can take several forms.

For example, independent loggers, who purchase public or private stumpage, sell their logs to mills or other outlets. Mills themselves often sort the logs they receive from the woods, selling some to other types of mills or to other outlets, so as to direct each log to the particular type of mill and product for which it is best suited. Also, the recent development of the log export market has introduced log dealer firms specializing in putting together shipments of certain kinds of logs for specific export orders. The prices reported here reflect all of the above kinds of transactions.

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[3] The open log market refers to log transactions between different individuals or independent firms (not between different departments of the same or related firms). The transactions involve logs in rafts--in rivers, Puget Sound or other harbors--or at dryland locations and do not include stumpage sales of standing timber. Northwest Oregon is defined here as approximately from Salem northward.

Most log transactions are on the basis of log grade, as defined by the Puget Sound, Grays Harbor, and Columbia River Log Scaling and Grading Bureaus. The various peeler and saw-log grades were developed to indicate the use for which individual logs are best suited. For example, peeler log grades originally indicated those logs suitable for the rotary peeling of clear veneer. In practice today, many peeler grade logs are actually sawn, and many saw-log grade logs go into veneer for structural grades of plywood. However, the grade distinctions continue to reflect differences in end-product value.

Export Log Sales

The "export sales" classification includes all log transactions that are identified for export, whether at initial scaling points, intermediate points, or final delivery points alongside ship.

Preparing logs for export generally involves extra sorting, towing, trimming, scaling, storage, and financing, as compared with logs destined for domestic use. Logs for domestic use often have some of these same kinds of costs, but usually not as much. This is one reason for export log prices being higher than water or inland prices.

Another reason for higher export log prices is the general requirement that export logs be mostly free of defect and have fewer large knots. This makes them better than the "average" within each log grade, and hence of more value. A third possible reason for higher export prices lies in the general competitive situation of the market. That is, a premium must be paid to divert logs from domestic channels and into export markets to compensate for uncertainty over the long-term availability of this special market, potential government controls, and the risk of alienating steady domestic customers or public opinion.

Export dealers have told us that the logs they handle have a higher relative value to overseas purchasers, who can afford to carry the extra costs of the additional handling and additional transactions through the various levels of log dealers and export trading companies.

Table 1.--*Douglas-fir peeler log prices, western Washington and northwest Oregon, 1963-68*

(Dollars per thousand board feet, Scribner log scale)

Log grade and year	Water and inland sales	Export sales	All sales
No. 1 peeler:			
1963	111.30	135.00	111.40
1964	114.80	123.90	114.80
1965	121.80	140.30	122.40
1966	125.70	142.00	127.60
1967	128.50	155.80	137.90
1968	143.30	155.60	149.40
No. 2 peeler:			
1963	99.90	--	99.90
1964	102.20	112.50	102.30
1965	109.40	117.50	109.50
1966	114.00	128.30	114.90
1967	117.60	133.10	122.30
1968	125.50	135.40	128.60
No. 3 peeler:			
1963	83.90	88.80	84.00
1964	84.40	97.40	85.00
1965	92.50	100.70	92.80
1966	96.80	103.40	97.70
1967	100.70	105.70	103.00
1968	108.80	111.20	110.20
SFP or SM:[1]			
1963	71.20	75.00	72.00
1964	73.40	82.20	74.50
1965	78.50	89.10	80.30
1966	83.60	89.90	86.10
1967	84.30	94.20	89.90
1968	96.90	103.50	100.80
Average:			
1963	86.00	76.00	85.20
1964	85.80	86.20	85.90
1965	93.90	93.90	93.90
1966	97.90	96.40	97.50
1967	103.80	108.50	105.90
1968	109.80	112.40	111.00

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[1] Special fir peeler or special mill grade.

Source: Pacific Northwest Forest and Range Experiment Station compilation of regional log values based on composite log sales analyses of Industrial Forestry Association, Portland, Oregon. These prices may reflect costs of towing, sorting, bundling, or other handling, depending on the point of sale in each transaction. Data for 1963 include third and fourth quarters only.

Table 2.--*Douglas-fir saw-log prices, western Washington and northwest Oregon, 1963-68*

(Dollars per thousand board feet, Scribner log scale)

Log grade and year	Water and inland sales	Export sales	All sales
No. 1 saw log:			
1963	67.30	--	67.30
1964	68.30	--	68.30
1965	72.10	78.30	72.20
1966	73.20	72.00	73.20
1967	70.80	93.90	72.70
1968	89.20	99.60	90.90
No. 2 saw log:			
1963	61.90	69.70	62.70
1964	63.50	71.70	64.90
1965	66.60	78.70	67.90
1966	67.60	80.50	70.00
1967	67.80	85.00	73.40
1968	79.10	97.90	87.50
No. 3 saw log:			
1963	50.60	58.20	52.70
1964	52.10	60.10	53.40
1965	54.20	60.70	55.40
1966	54.90	63.90	56.10
1967	54.60	70.70	57.90
1968	63.90	88.00	70.60
Mixed grade:			
1963	--	--	--
1964	60.40	78.80	64.60
1965	66.60	81.40	69.70
1966	71.00	78.20	74.70
1967	72.30	80.40	78.40
1968	81.80	96.40	86.60
Ungraded:[1/]			
1963	51.20	54.30	52.00
1964	38.30	58.40	39.50
1965	44.20	51.10	44.20
1966	49.20	78.30	50.50
1967	46.30	68.30	53.10
1968	63.40	71.40	66.90
Average:			
1963	57.90	61.60	58.50
1964	57.70	68.50	59.50
1965	61.50	72.50	63.00
1966	62.30	77.10	65.00
1967	61.80	80.00	68.90
1968	75.00	93.20	82.00

[1/] Excludes cull logs and utility logs.

Source: Pacific Northwest Forest and Range Experiment Station compilation of regional log values based on composite log sales analyses of Industrial Forestry Association, Portland, Oregon. These prices may reflect costs of towing, sorting, bundling, or other handling, depending on the point of sale in each transaction. Data for 1963 include third and fourth quarters only.

Table 3.--*Western hemlock log prices, western Washington and northwest Oregon, 1963-68*

(Dollars per thousand board feet, Scribner log scale)

Log grade and year	Water and inland sales	Export sales	All sales
Peeler log:			
1963	64.20	72.60	66.20
1964	66.90	80.10	72.20
1965	77.20	84.80	81.00
1966	81.80	84.30	83.70
1967	82.90	96.80	94.70
1968	93.30	110.20	109.00
SFP or SM:[1]			
1963	57.40	60.70	60.10
1964	88.00	71.90	76.40
1965	65.00	84.80	78.20
1966	66.10	80.80	79.20
1967	69.10	88.00	87.20
1968	89.40	101.00	100.40
No. 1 saw log:			
1963	59.00	67.50	62.30
1964	62.30	75.60	68.80
1965	71.60	78.80	76.10
1966	74.80	87.70	84.60
1967	75.30	91.60	90.00
1968	86.80	105.60	104.40
No. 2 saw log:			
1963	47.50	60.10	51.90
1964	50.10	64.60	55.20
1965	52.70	71.00	63.10
1966	53.30	77.80	66.50
1967	53.30	81.70	75.50
1968	65.60	96.00	89.90
No. 3 saw log:			
1963	40.30	56.20	42.70
1964	41.90	56.70	44.30
1965	44.40	62.60	50.40
1966	44.60	68.90	49.60
1967	45.20	71.70	57.30
1968	55.20	87.20	74.30
Mixed grade:			
1963	--	--	--
1964	46.70	61.70	56.60
1965	48.20	67.60	59.40
1966	48.30	72.60	62.40
1967	50.60	76.20	67.70
1968	63.40	89.70	81.00
Ungraded:[2]			
1963	44.70	54.90	50.60
1964	41.00	53.40	45.80
1965	42.80	63.30	48.50
1966	44.30	60.50	48.60
1967	45.00	66.70	52.10
1968	55.80	81.00	63.90
Average:			
1963	46.90	56.80	51.60
1964	47.60	62.20	55.20
1965	49.30	70.00	60.40
1966	49.80	76.00	64.20
1967	49.20	80.60	70.30
1968	62.20	96.00	87.60

[1] "Suitable for peeling" or special mill grade.

[2] Excludes cull logs and utility logs.

Source: Pacific Northwest Forest and Range Experiment Station compilation of regional log values based on composite log sales analyses of Industrial Forestry Association, Portland, Oregon. These prices may reflect costs of towing, sorting, bundling, or other handling, depending on the point of sale in each transaction. Data for 1963 include third and fourth quarters only.

Table 4.--*Noble fir log prices, western Washington and northwest Oregon, 1963-68*

(Dollars per thousand board feet, Scribner log scale)

Log grade and year	Water and inland sales	Export sales	All sales	Log grade and year	Water and inland sales	Export sales	All sales
Peeler log:				No. 3 saw log:			
1963	66.60	96.80	94.80	1963	43.00	57.60	50.30
1964	78.70	103.60	102.20	1964	43.60	66.80	57.70
1965	106.40	133.90	132.40	1965	45.80	72.00	64.10
1966	102.00	145.50	144.90	1966	46.10	75.20	69.70
1967	114.00	150.20	149.90	1967	47.40	75.70	73.30
1968	153.90	168.00	167.50	1968	69.50	82.10	80.00
SFP or SM:[1]				Mixed grade:			
1963	53.00	73.30	72.90	1963	--	--	--
1964	68.70	78.60	78.20	1964	60.70	64.10	63.70
1965	84.30	102.50	101.60	1965	62.00	87.00	81.90
1966	83.30	116.40	115.50	1966	46.70	85.40	75.40
1967	85.80	124.20	123.40	1967	51.40	89.50	77.50
1968	104.10	136.60	135.90	1968	71.00	99.10	97.30
No. 1 saw log:				Ungraded:[2]			
1963	57.60	87.90	86.70	1963	51.20	57.60	55.80
1964	77.50	94.10	93.50	1964	35.80	--	35.80
1965	92.30	122.60	120.90	1965	43.70	94.10	82.40
1966	82.80	131.70	130.50	1966	40.00	--	40.00
1967	86.70	143.20	142.50	1967	41.50	38.10	41.50
1968	130.20	157.90	156.20	1968	49.80	--	49.80
No. 2 saw log:				Average:			
1963	50.80	65.50	62.10	1963	51.50	74.90	71.00
1964	50.50	69.80	62.90	1964	54.60	84.80	80.50
1965	53.90	88.40	84.00	1965	63.20	105.30	100.60
1966	63.30	96.40	94.60	1966	57.70	116.20	112.40
1967	67.40	101.40	100.30	1967	48.00	123.90	114.20
1968	84.90	113.30	110.90	1968	97.80	137.40	135.00

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[1] "Suitable for peeling" or special mill grade.

[2] Excludes cull logs and utility logs.

Source: Pacific Northwest Forest and Range Experiment Station compilation of regional log values based on composite log sales analyses of Industrial Forestry Association, Portland, Oregon. These prices may reflect costs of towing, sorting, bundling, or other handling, depending on the point of sale in each transaction. Data for 1963 include third and fourth quarters only.

Table 5.--*White fir log prices, western Washington and northwest Oregon, 1963-68*

(Dollars per thousand board feet, Scribner log scale)

Log grade and year	Water and inland sales	Export sales	All sales
Peeler log:			
1963	64.90	70.90	65.60
1964	66.60	81.60	70.60
1965	76.10	84.80	79.60
1966	79.30	91.70	88.60
1967	81.00	95.60	92.70
1968	87.10	107.00	104.90
SFP or SM:[1]			
1963	58.90	61.60	60.20
1964	59.70	74.00	66.90
1965	66.40	78.40	73.90
1966	68.40	82.20	79.40
1967	68.00	85.20	82.60
1968	79.90	97.80	97.20
No. 1 saw log:			
1963	59.40	66.50	61.00
1964	62.90	76.00	67.60
1965	71.40	80.40	76.40
1966	74.30	87.60	83.60
1967	74.70	90.40	87.90
1968	86.10	101.20	100.00
No. 2 saw log:			
1963	51.00	61.10	53.00
1964	52.60	62.40	54.40
1965	55.40	72.40	62.70
1966	56.50	78.60	70.30
1967	53.00	81.90	76.20
1968	63.80	94.40	90.10
No. 3 saw log:			
1963	41.20	57.00	45.40
1964	42.90	57.10	44.30
1965	45.40	65.10	49.80
1966	44.80	71.30	53.90
1967	47.00	74.80	60.30
1968	53.10	85.80	72.20
Mixed grade:			
1963	--	--	--
1964	46.80	60.20	54.70
1965	60.40	70.40	66.20
1966	55.00	79.00	71.70
1967	53.60	82.00	75.00
1968	63.70	91.40	81.00
Ungraded:[2]			
1963	41.60	55.20	48.30
1964	38.50	54.30	44.00
1965	42.60	65.70	46.90
1966	42.60	59.80	50.60
1967	44.40	68.70	49.80
1968	51.70	86.70	59.10
Average:			
1963	51.10	58.40	53.40
1964	50.90	63.10	55.30
1965	56.20	73.10	63.90
1966	55.20	80.00	71.10
1967	53.10	83.90	75.60
1968	61.20	95.10	87.20

[1] "Suitable for peeling" or special mill grade.

[2] Excludes cull logs and utility logs.

Source: Pacific Northwest Forest and Range Experiment Station compilation of regional log values based on composite log sales analyses of Industrial Forestry Association, Portland, Oregon. These prices may reflect costs of towing, sorting, bundling, or other handling, depending on the point of sale in each transaction. Data for 1963 include third and fourth quarters only.

Table 6.--*Sitka spruce log prices, western Washington and northwest Oregon, 1963-68*

(Dollars per thousand board feet, Scribner log scale)

Log grade and year	Water and inland sales	Export sales	All sales
Select log:			
1963	88.40	99.20	91.20
1964	99.30	121.60	113.00
1965	138.30	140.80	140.20
1966	136.30	147.00	144.80
1967	147.60	151.00	150.50
1968	166.00	154.70	156.00
SFP or SM:[1]			
1963	--	--	--
1964	--	--	--
1965	--	--	--
1966	66.10	92.90	88.10
1967	67.60	109.30	92.34
1968	--	102.00	102.00
No. 1 saw log:			
1963	71.30	83.20	74.90
1964	76.90	103.80	92.80
1965	107.70	121.90	118.10
1966	101.70	132.90	127.90
1967	106.10	141.40	135.30
1968	126.80	163.60	157.80
No. 2 saw log:			
1963	51.70	64.70	55.20
1964	57.70	76.20	65.00
1965	71.70	80.70	77.30
1966	62.40	99.90	87.40
1967	64.20	95.50	89.50
1968	77.90	118.50	111.50
No. 3 saw log:			
1963	41.90	48.10	42.80
1964	43.10	53.20	45.70
1965	46.30	47.10	46.60
1966	46.50	63.40	49.90
1967	44.30	67.10	52.10
1968	49.30	85.70	69.80
Mixed grade:			
1963	--	--	--
1964	50.30	68.90	60.10
1965	55.00	84.50	64.40
1966	67.60	79.00	73.40
1967	61.00	97.20	77.20
1968	79.50	100.50	86.60
Ungraded:[2]			
1963	51.20	51.40	51.20
1964	33.60	47.70	40.50
1965	43.80	72.70	46.70
1966	46.10	65.50	50.40
1967	44.00	46.70	44.20
1968	57.00	102.60	66.40
Average:			
1963	56.00	70.00	59.30
1964	58.10	83.40	69.00
1965	66.10	94.90	81.20
1966	64.40	107.30	89.60
1967	62.00	107.00	92.60
1968	82.40	129.10	115.60

[1] "Suitable for peeling" or special mill grade.

[2] Excludes cull logs and utility logs.

Source: Pacific Northwest Forest and Range Experiment Station compilation of regional log values based on composite log sales analyses of Industrial Forestry Association, Portland, Oregon. These prices may reflect costs of towing, sorting, bundling, or other handling, depending on the point of sale in each transaction. Data for 1963 include third and fourth quarters only.

Table 7.--*Western redcedar log prices, western Washington and northwest Oregon, 1963-68*

(Dollars per thousand board feet, Scribner log scale)

Log grade and year	Water and inland sales	Export sales	All sales	Log grade and year	Water and inland sales	Export sales	All sales
No. 1 saw log:				Mixed grade:			
1963	74.30	83.00	74.50	1963	--	--	--
1964	76.60	84.80	76.80	1964	50.40	43.80	49.50
1965	84.20	97.00	85.10	1965	47.80	62.70	48.40
1966	87.10	101.60	88.90	1966	44.70	64.40	46.70
1967	81.60	112.00	87.70	1967	47.90	62.80	49.90
1968	98.00	127.20	102.60	1968	61.70	73.20	64.20
No. 2 saw log:				Ungraded:[1]			
1963	51.50	64.30	51.80	1963	47.40	55.70	47.50
1964	54.10	71.70	54.60	1964	46.00	44.80	46.00
1965	57.50	77.20	59.00	1965	48.50	61.00	48.50
1966	60.10	82.60	62.50	1966	54.40	61.20	54.50
1967	61.00	85.60	66.50	1967	43.80	59.60	52.50
1968	75.60	102.70	80.80	1968	55.40	89.00	56.50
No. 3 saw log:				Average:			
1963	41.70	57.30	42.30	1963	51.80	64.10	52.10
1964	45.30	51.00	45.60	1964	54.10	60.10	54.30
1965	45.70	54.60	46.20	1965	56.20	73.50	57.30
1966	43.60	61.90	44.90	1966	56.40	79.00	58.40
1967	46.30	65.30	51.40	1967	57.60	77.60	62.50
1968	54.90	70.80	57.70	1968	71.20	94.10	75.40

[1] Excludes cull logs and utility logs.

Source: Pacific Northwest Forest and Range Experiment Station compilation of regional log values based on composite log sales analyses of Industrial Forestry Association, Portland, Oregon. These prices may reflect costs of towing, sorting, bundling, or other handling, depending on the point of sale in each transaction. Data for 1963 include third and fourth quarters only.

Table 8.--*Western white pine log prices, western Washington and northwest Oregon, 1963-68*

(Dollars per thousand board feet, Scribner log scale)

Log grade and year	Water and inland sales	Export sales	All sales	Log grade and year	Water and inland sales	Export sales	All sales
Peeler log:				No. 3 saw log:			
1963	79.00	--	79.00	1963	43.50	36.00	43.20
1964	73.60	60.30	69.50	1964	43.00	43.50	43.20
1965	89.40	59.40	83.80	1965	46.60	41.60	45.50
1966	77.80	87.30	86.40	1966	45.40	39.40	41.60
1967	84.40	93.30	90.80	1967	45.40	39.50	43.00
1968	108.10	96.10	97.60	1968	52.20	46.80	48.40
SFP or SM:[1]				Mixed grade:			
1963	80.80	--	80.80	1963	--	--	--
1964	58.40	--	58.40	1964	62.80	63.90	63.20
1965	76.90	77.80	76.90	1965	52.00	56.60	52.40
1966	70.30	97.10	93.40	1966	50.10	64.90	59.30
1967	72.10	103.30	91.60	1967	41.40	73.90	55.60
1968	88.20	112.20	108.20	1968	46.40	82.90	55.40
No. 1 saw log:				Ungraded:[2]			
1963	57.00	56.60	56.80	1963	42.30	54.80	44.90
1964	65.80	54.60	60.20	1964	42.50	--	42.50
1965	83.30	66.90	80.80	1965	36.60	--	36.60
1966	65.00	80.20	78.20	1966	36.50	--	36.50
1967	77.60	83.40	82.30	1967	46.70	44.90	45.20
1968	90.70	77.80	78.80	1968	58.80	74.00	65.00
No. 2 saw log:				Average:			
1963	49.50	51.90	49.90	1963	48.60	53.50	49.40
1964	55.00	45.70	52.60	1964	49.10	45.20	47.50
1965	62.90	54.80	61.60	1965	54.40	54.60	54.50
1966	56.00	59.00	58.10	1966	42.90	65.70	54.20
1967	57.40	72.90	66.90	1967	52.90	71.00	63.60
1968	68.50	66.20	67.00	1968	53.90	65.50	59.50

[1] "Suitable for peeling" or special mill grade.

[2] Excludes cull logs and utility logs.

Source: Pacific Northwest Forest and Range Experiment Station compilation of regional log values based on composite log sales analyses of Industrial Forestry Association, Portland, Oregon. These prices may reflect costs of towing, sorting, bundling, or other handling, depending on the point of sale in each transaction. Data for 1963 include third and fourth quarters only.

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A. Forest Service RESEARCH NOTE

FEB

PNW-128 August 1970

A METHOD FOR SAMPLING
YEASTS AND BACTERIA IN SOUND WOOD

by

Donald M. Knutson, *Plant Pathologist*

ABSTRACT

A tubular chisel is described and methods are presented for sampling populations of yeasts and bacteria within the sound wood of living trees.

Good data on the numbers and kinds of unicellular organisms, including yeasts and bacteria, within undecayed wood are needed to evaluate their role in causing diseases of wood, in microbial successions, and in formation of fermentation byproducts in logs, considered important as insect attractants.[1]

The method described here, originally developed for sampling aspen logs,[2] has proven useful for quantitative sampling of unicellular organisms in undecayed wood. Cores of wood are extracted with a hollow, cylindrical chisel. The sap from the wood cores is aseptically expressed, diluted, and plated on agar media.

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[1] K. Graham. Anaerobic induction of primary chemical attractancy for Ambrosia beetles. Can. J. Bot. 46: 905-908. 1968.

[2] Donald Maurice Knutson. Wetwood in trembling aspen *(Populus tremuloides* Michx.). 152 pp. 1968. (Ph.D. thesis, Univ. Minn., School of Forestry.

THE METHOD

The chisel consists of a hollow steel cylinder sharpened on one end and with a flattened lip on the other (fig. 1). It is 8 centimeters long and has a 1.3-centimeter (1/2-inch) inside diameter at the cutting edge.

With the chisel, wood cylinders are taken from disks of wood (with the grain) (fig. 2). The sampling method and analysis involve these steps:

1. Bolts, approximately 1 meter long, are cut from chosen trees, sealed in plastic bags, taken immediately to the laboratory, and frozen until needed. Drying must be minimized since the method depends on extraction of sap.

2. Disks of wood, approximately 5 to 6 centimeters thick, are cut from the center of the bolt with a chain saw. To reduce contamination of the cut wood surface, the bark should be removed before cutting the disk.

3. Sampling points can be chosen and replicated in a disk in any variety of designs, depending on sampling objectives. For example, one can compare the number of organisms from different zones of sapwood or contrast sapwood with heartwood organisms.

4. Cylinders are cut by driving the chisel along the grain of the selected sampling point while the wood disks are frozen, to facilitate cutting and prevent changes in moisture content of the wood. The chisel is dipped in 95 percent alcohol and flamed for each operation. The cylinders are easily removed from the chisel because of the larger diameter inside the chisel above the cutting edge (fig. 1).

5. Both ends of each cylinder are cut off with a hacksaw or bandsaw blade which has been dipped in alcohol and flamed. The cylinders should be reduced to an established length (3-4 centimeters). After the individual cylinder is cut, it is held with a forceps, flamed with 95 percent alcohol, and placed in a presterilized length (15 centimeters) of rubber tubing (1.3-centimeter (1/2-inch) inside diameter).

6. The rubber tubing containing the wood cylinder is placed between the platens of a Carter Laboratory Press[3] and pressed at 3,000 pounds per square inch (p.s.i.). The press is positioned at a slant so that the sap will run down the tubing into a sterile vial.

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[3] The use of proprietary or brand names does not imply approval of the product to the exclusion of others which may also be suitable.

7. The expressed sap is diluted by standard dilution techniques and cultured on appropriate medium. Difco Nutrient Agar is a good standard medium. Petri dishes are incubated at 25-30° C. for 3 days before colonies are counted. Since many colonies will be small, counts should be made under magnification. Data can be expressed as the number of colonies per milliliter of expressed sap, or related to volume of wood sampled.

Although the data cannot be considered the total number of organisms, this method does provide a means of quantifying relative numbers of microbes in an environment which is very difficult to study--the inside of a tree.

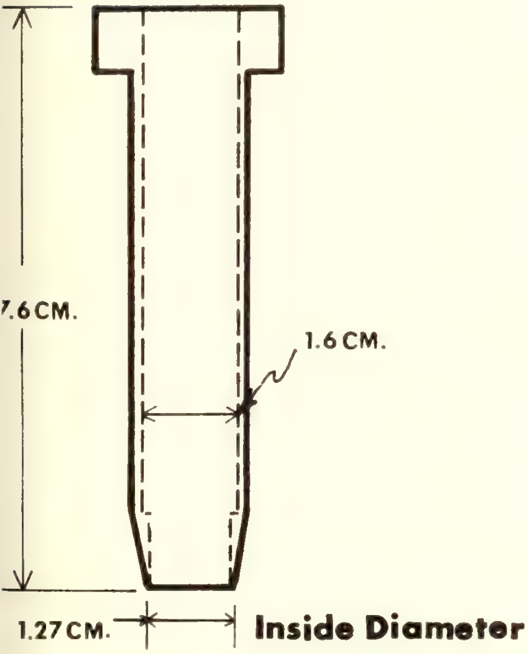

Figure 1.--*Hollow circular steel chisel for taking wood cylinders.*

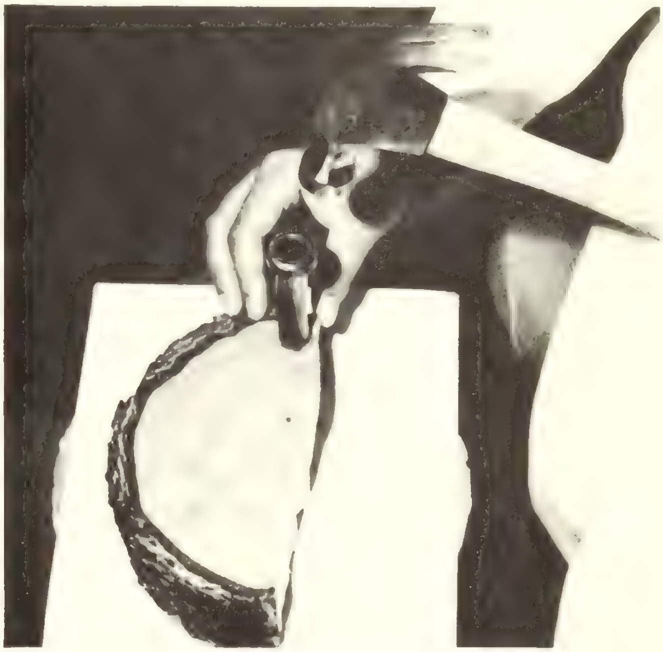

Figure 2.--*Method of taking wood cylinders with the chisel.*

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.A. Forest Service RESEARCH NOT

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TECH. & AGR. DIV.

PNW-129 *September 1970*

WHITE SPRUCE CONE AND SEED PRODUCTION IN INTERIOR ALASKA, 1957-68

by John C. Zasada, *Research Forester*

and Leslie A. Viereck, *Principal Plant Ecologist*[1]

ABSTRACT

Estimates of seedfall per acre, seed dispersal over time, cone production by individual trees, number of seeds per cone and per tree, and cone crop rating are reported from white spruce stands in interior Alaska for the period 1957-68. These observations indicate that very good seed years may be separated by at least 10 to 12 years although, during this interval, individual stands may produce from one to several fair or good cone crops.

During the period 1957-68, investigators have studied various aspects of white spruce cone and seed production in interior Alaska. Their findings are scattered in journals, office reports, research papers, annual reports, and unpublished master's theses and are not readily available. We have summarized this knowledge, used data from our own studies, and made general conclusions about white spruce seed production, an extremely important factor in both natural and artificial regeneration of white spruce.

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[1] We would like to acknowledge the work done by Drs. Robert Funsch and Robert A. Gregory in their investigations of seed production in Alaska from 1957 to 1962 and the field and laboratory assistance of Mrs. Joan Foote.

CONE CROP RATINGS

Cone crop estimates for varying numbers of stands have been made annually from 1957-68 (except in 1963). Werner's (1964) data for the period 1958-61 are the most complete and are an average value for a number of stands in interior Alaska along the Nenana and Alaska Highways (fig. 1). The data for the remaining years are for individual stands in the vicinity of Fairbanks, Alaska (1964-65 data from Smith[2]).

The cone crop rating system of 1 to 10, used by investigators in Alaska, admittedly is subjective and distinguishing between two adjacent ratings on the scale is often difficult. However, we feel that it does provide a reliable basis for comparing the relative cone production between stands and between individual years.

Cone Crop Rating System

Class	Rating
Very poor	1. No cones on any trees
	2. Few cones on occasional trees
Poor	3. Few cones on 25 percent of trees
	4. Few cones on 25 percent of trees--many cones on occasional trees
Fair	5. Few cones on 75 percent of trees
	6. Few cones on 75 percent of trees--many cones on some trees
Good	7. Some cones on all trees
	8. Many cones on some trees--some cones on all trees
Very good	9. Many cones on 75 percent of trees--some cones on all trees.
	10. Many cones on all trees

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[2] M. C. Smith. Red squirrel *(Tamiasciurus hudsonicus)* ecology during spruce cone failure in Alaska. 1967. (Unpublished master's thesis on file at Univ. Alaska, College.)

From the tabulation shown below, we can make the following observations. The 1958 crop was generally good to very good throughout the interior. Based on these data, the next best crop may have occurred in 1968; however, in 1966 and 1967 good crops were observed in individual stands. Cone crops for the years 1959-65 generally were poor to fair.

Year	Cone crop rating	Study area
1957	5	Bonanza Creek-2
1958	9	Fairbanks vicinity
	9	Bonanza Creek-2
	8-9	Tanana Valley (Fairbanks to George Lake)
	8	Gerstle River
	8	Steese Highway (Central to Circle)
1959	4	Fairbanks vicinity
	4	Bonanza Creek-2
1960	3	Fairbanks vicinity
1961	3	Fairbanks vicinity
1962	4	Bonanza Creek-2
1963	--	--
1964	2	Bonanza Creek-1
1965	1	Bonanza Creek-1
1966	3-4	Fairbanks vicinity
1967	4-5	Bonanza Creek-1
	7	Bonanza Creek-2
	7	Chena River-1
	8	Chena River-2
1968	7	Bonanza Creek-1
	7	Bonanza Creek-2
	7	T-field
	7	Gerstle River

However, even during poor to fair years, it is possible to locate stands or individual trees which produce better than average cone crops. Table 1 indicates the variation which existed for the average values reported by Werner (1964) for the years 1959-61.

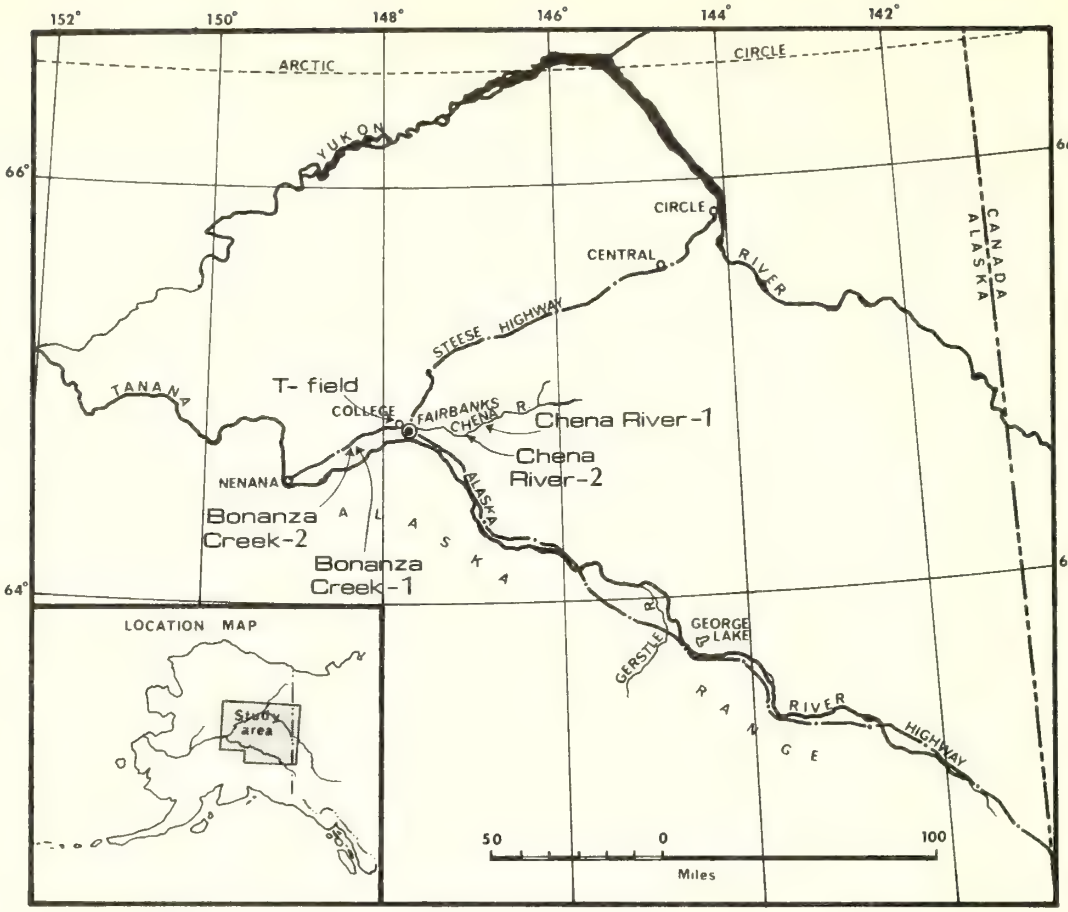

Figure 1.--*Location of study areas in interior Alaska, 1957-68.*

Table 1.--*Number of stands*[1] *in each cone crop class along the Nenana and Alaska Highways, 1959-61*

Year and location	Cone crop ratings									
	1	2	3	4	5	6	7	8	9	10
1959:										
Nenana Highway	8	8	6							
Alaska Highway			3	10		7				
1960:										
Nenana Highway			3	2	3	5	1			
Alaska Highway	8	7	8	8	4	5				
1961:										
Nenana Highway		1	2	5	6	5				
Alaska Highway	1	13	4	8	5	3				

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[1] Stands in which ratings were made generally described as well to moderately well stocked and mixed in composition (e.g., white spruce-black spruce and white spruce-hardwood).

Table 2.--*Cone production of selected white spruce during 1967 and 1968*

Year and area	Tree number									
	1	2	3	4	5	6	7	8	9	10
	Number of cones									
1967:[1/]										
Bonanza Creek-1	8	40	15	50	90	75	130	15	90	20
Bonanza Creek-2	250	75	50	40	140	80	30	80	130	120
1968:[2/]										
Chena River-1	587	289	879	390	619	1,010	1,234	2,251		
Bonanza Creek-2	1,977	1,873								

[1/] Cone counts made of dominant trees from the ground with binoculars.

[2/] Cone counts are actual counts of cones picked from felled trees; these trees were dominants and selected because they had large quantities of cones.

CONE PRODUCTION BY INDIVIDUAL TREES

In 1967, 10 dominant white spruces in Bonanza Creek-1 produced an average of 53 cones per tree during a fair year (rating 4); at Bonanza Creek-2, 10 dominants produced an average of 77 cones per tree during a good year (rating 7). These counts were made with binoculars. During the fall of 1968, trees which appeared to have produced more cones than their immediate neighbors were felled and all the cones were collected and counted. Two such trees at Bonanza Creek-2 produced an average of 1,925 cones per tree, and eight trees near the Chena River-1 plot, an average of 907 (table 2).

QUANTITY AND QUALITY OF SEED IN CONES

Although annual variation in the average number of seeds and percent of sound seed per cone (table 3) exists, the best cone and seed year on record (1958, rating 8-9) appears to have produced the highest average number of seeds (83) and the highest sound seed percentage (74). Other years produced an average of 31 seeds per cone with about 37 percent sound (1959, rating 4); 12 seeds per cone, 53 percent sound (1960, rating 3); and 65 seeds per cone, 38 percent sound (1961, rating 3) (Werner 1964 and Northern Forest Experiment Station 1960-61). In 1968, cones of individual trees (table 3, trees 3 and 8) in the Chena River-1 area produced seed with about the quantity and quality of that produced in 1958, but the average for all trees (52 seeds per cone, 64 percent sound) was below the 1958 average.

Tables 2 and 3, considered together, provide an estimate of the quantity of seed produced in 1968 by trees in the vicinity of the Chena River-1 and Bonanza Creek-2 stands:

Area	Total seeds per tree	Sound seeds per tree
Chena River-1	54,490	34,873
Bonanza Creek-2	63,666	38,776

SEEDFALL IN UNDISTURBED WHITE SPRUCE STANDS

The seedfall data for Bonanza Creek-2 (table 4) seems to indicate that a direct relationship may exist between cone crop rating and both total seedfall and the quantity of sound seed per acre. However, this relationship is confounded by such factors as disease *(Chrysomyxa pirolata)* (Zasada and Gregory 1969), frost,[3] insects (Werner 1964), and the red squirrel *(Tamiasciurus hudsonicus)* (Brink,[4] Smith,[5] Streubel,[6] Brink and Dean 1966). Werner's data showed that, in years with similar cone crop ratings (rating 3-4 in 1959, 1960, 1961), insect damage to seed may vary significantly: 1959--11.5 sound seeds per cone; 1960--6.5 sound seeds; and 1961--24.7 sound seeds (table 3). This would result in similar variation in the quality of seedfall. During 1967, Streubel estimated that squirrels harvested between 59 and 88 percent of the cone crop on plots with active middens and between 4 and 21 percent on plots without active midden areas. This would greatly reduce the "effective" cone crop and the quantity of seed dispersed.

Dispersal of the annual seed crop usually begins during mid- to late-August. Although seed continues to fall during the next year, the majority of the seed is dispersed over a relatively short period of time (2-3 months). For example, it appears that the first dispersal of any of the 1968 seed crop occurred between August 13 and 20 in three of four study stands. The greatest quantity of seed fell during the first 7 to 10 days of September; and 79 to 87 percent of the seedfall for the 4½-month observation period (August 6 to mid-December) occurred during September and October (fig. 2 and table 5).

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[3] J. C. Zasada, in preparation.

[4] C. H. Brink. Spruce seed as a food of the squirrels *(Tamiasciurus hudsonicus)* and *Glaucomys sabrinus* in interior Alaska. 1964. (Unpublished master's thesis on file at Univ. Alaska, College.)

[5] See footnote 2, p. 2.

[6] D. P. Streubel. Food storing and related behavior of red squirrels *(Tamiasciurus hudsonicus)* in interior Alaska. 1968. (Unpublished master's thesis on file at Univ. Alaska, College.)

Table 3.--*White spruce seed and seed quality based on extraction of seed collected from individual cones*

Year and tree number	Average number seeds per cone[1/][2/]	Sound seed per cone	Percent sound seed[3/]
1958	83.3(11-146)	62.1	74.1(0-100)
1959	30.7(0-116)	11.5	37.4(0-86)
1960	12.2(0-66)	6.5	53.3(0-100)
1961	64.6(15-135)	24.7	38.2(0-82)
1962:			
Nenana Highway-1	43.1	24.1	55.9
Nenana Highway-2	61.8	14.6	23.6
Nenana Highway-3	80.2	23.1	28.8
$\overline{X}$	61.7	20.6	36.1
1968, Chena River-1:			
Tree 1	34.3	25.7	74.9
2	41.6	34.1	82.0
3	80.3	51.3	63.9
4	32.3	14.5	44.9
5	46.6	20.5	44.0
6	48.3	25.1	52.0
7	51.5	22.1	42.9
8	79.7	61.3	76.9
Random collection (from felled trees)	52.9	25.9	49.0
$\overline{X}$	51.9	31.2	63.6
1968, Bonanza Creek-2:			
Tree 1	41.1	27.1	65.9
2	24.6	12.8	52.0
Random collection (from crowns of six trees)	41.0	25.8	62.9
$\overline{X}$	35.6	21.9	60.3

[1/] Values in parentheses denote range.

[2/] 1968 data are based on seed extracted from a random sample of 10 cones from each tree except where stated.

[3/] 1968 data on percent sound seed are based on cutting test of 200 seeds for each tree.

CONCLUSIONS

Although these data are limited, they do provide some useful information concerning cone and seed production in white spruce stands of interior Alaska. Using this information, we can make several general statements.

The between-stand variation in cone and seed production for any given year in an area the size of interior Alaska or even a drainage, such as that of the Yukon or Tanana Rivers, can be significant. Therefore, conclusions concerning the cone and seed crop in such areas based on observations from only one or two stands may be misleading. Similarly, an average value for any cone and seed production parameters for stands or even trees within a stand, although useful, may be of limited value for a particular stand or tree. This variation (both between stands and between trees) seems to be consistent with that reported for white spruce in other parts of its range[7] and for Norway spruce in Finland (Sarvas 1968) and Sweden (Andersson 1965), but not with Waldron's[8] cone crop data for white spruce in Saskatchewan and Manitoba.

The interval between very good cone and seed years may be closer to the 12-13 years reported by Sarvas (1957) for Norway spruce in Finland than the 6-7 years in the Prince George Forest District of British Columbia,[8] or the 3-4 years in the Duck Mountain and Porcupine Forest Reserves in Manitoba (Rowe 1955). However, the Alaska data seem to indicate that between the generally very good cone and seed years individual stands will produce from one to several fair or good cone crops.

Assuming that mortality of enlarging conelets is negligible, cone counts made prior to the harvest of cones by red squirrels (i.e., before August 1) provide the best estimate for determining periodicity of cone and seed crops. Seed trap studies, although they may directly relate to cone crop, provide an estimate of the seed reaching the ground and potentially available for natural regeneration but are probably not as reliable for determining the actual periodicity of cone and seed crops as July cone counts.

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[7] John Revel, British Columbia Forest Service, Red Rock Nursery, Prince George, B. C., personal correspondence.

[8] R. M. Waldron. Annual cone crops of white spruce in Saskatchewan and Manitoba 1923-1964. Can. Dep. Forest., Forest Res. Br., Progr. Rep., Proj. MS-158, 34 pp. 1965.

Table 4.--*Seedfall*[1] *in undisturbed white spruce stands*

Year and place	Cone crop rating	Seed	Sound seed	Sound seed[2]
		- - *Thousands per acre*	- -	*Percent*
1957:				
Bonanza Creek-2	5	138	86	62
1958:				
Bonanza Creek-2	9	16,512	10,733	65
1959:				
Bonanza Creek-2	4	123	27	22
1968:				
Bonanza Creek-2	7	334	136	41
Bonanza Creek-1	7	227	85	37
Chena River-1	7	214	55	26
T-field	7	396	157	40

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[1] Estimate obtained from seed collected in 1/4-milacre-square seed traps.

[2] Determined from cutting tests of all seed collected in seed traps.

Table 5.--*Total seedfall dispersed during monthly intervals for the period August to mid-December*

Interval	Bonanza Creek-1		Bonanza Creek-2		Chena River-1		T-field	
	Total seedfall	Filled seed	Total seedfall	Filled seed	Total seedfall	Filled seed	Total seedfall	Filled seed
	- - - - - - - -	- - - - - -	- - - - - *Percent*	- - - - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -
Aug. 6-Aug. 27	7.2	7.8	10.5	6.3	10.7	3.0	9.0	7.3
Aug. 27-Sept. 27	57.7	65.8	62.2	74.2	59.3	64.4	71.4	77.6
Sept. 27-Oct. 25	21.1	18.9	18.8	16.9	19.3	22.2	[1]15.8	12.7
Oct. 25-Dec. 16	14.0	7.5	8.5	2.6	10.7	10.4	[2]3.8	2.4

[1] Sept. 27-Nov. 4.
[2] Nov. 5-Dec. 16.

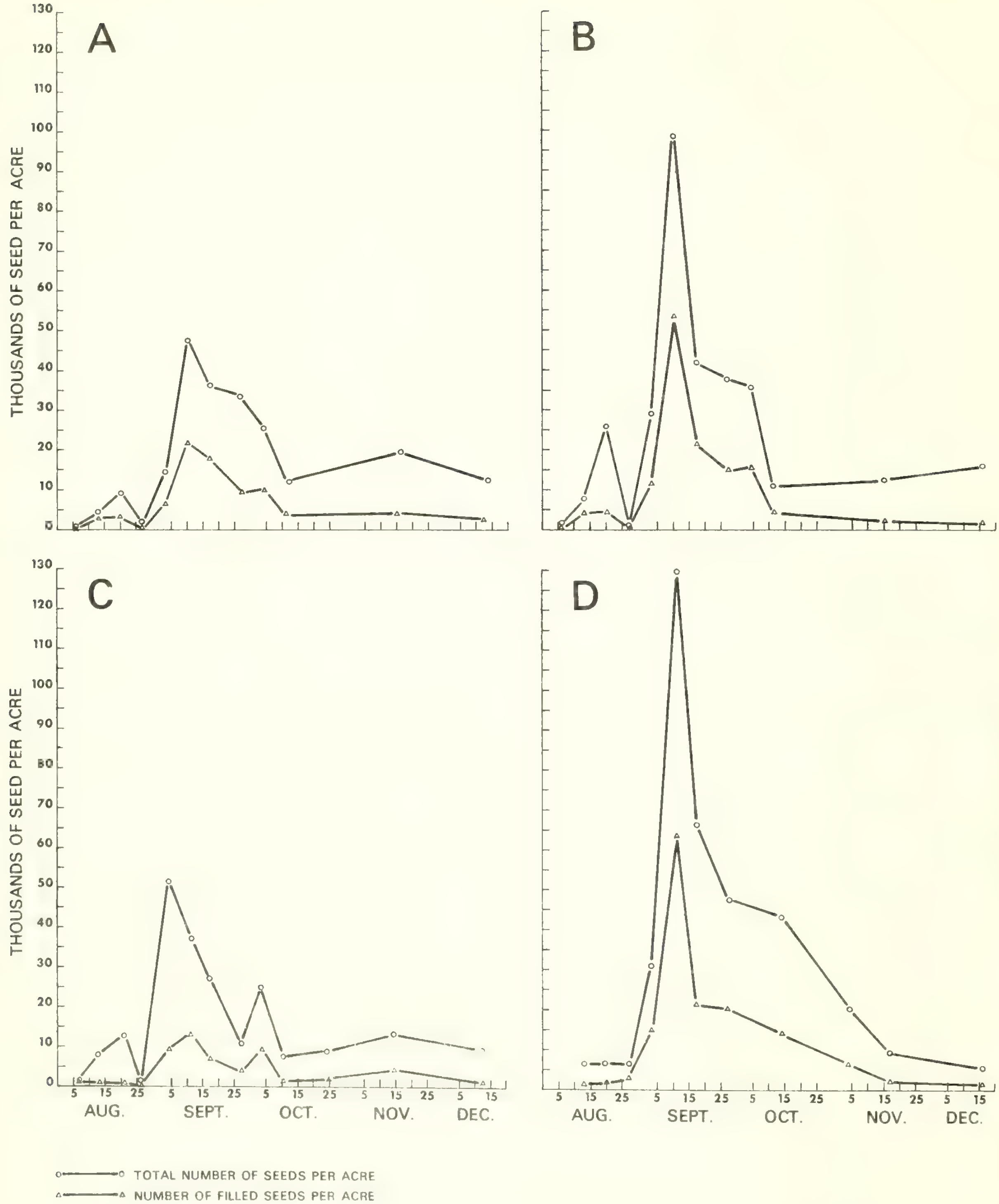

Figure 2.--*1968 seedfall for the period August to mid-December. A. Bonanza Creek-1; B. Bonanza Creek-2; C. Chena River-1; D. T-field. (Seed collected at about weekly intervals from August 6 to mid-October and once in November and December. Collections at the T-field plot were slightly different.)*

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A Forest Service RESEARCH NOTE

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PNW-130 *September 1970*

GROWTH OF DOUGLAS-FIR, PONDEROSA PINE, AND WESTERN LARCH SEEDLINGS FOLLOWING SEED TREATMENT WITH 30 PERCENT HYDROGEN PEROXIDE

by James W. Edgren, *Plant Ecologist*

and James M. Trappe, *Principal Mycologist*

ABSTRACT

Seeds of the three species were either cold stratified or soaked for 2 hours in 30 percent hydrogen peroxide. Subsequent growth of potted seedlings from treated and stratified seeds was measured at the end of 7 weeks and 1 year. Average size of 1-year-old western larch from H_2O_2*-treated seed was significantly less than those from stratified seed. In most instances, height growth, needle length, and ovendry weight of year-old Douglas-firs and ponderosa pines also tended to be less for seedlings from peroxide treated seed. Thus, use of 30 percent* H_2O_2 *for speeding germination in operational sowings is not recommended.*

INTRODUCTION

Hydrogen peroxide treatment has speeded germination of conifer and shrub seeds (Shearer and Tackle 1960, Trappe 1961, Stein 1965, Riffle and Springfield 1968). In view of this effect, Carter and Jones (1962) and others have suggested that H_2O_2 treatments might be used in nursery or direct seeding practice to shorten the time ungerminated seeds are exposed to fungi, seedeaters, or unfavorable weather. In fact, H_2O_2 at 40-volume strength has already been used in a nursery sowing of *Pinus elliottii* and *Pinus taeda* (Takacs 1964). Before H_2O_2 treatment is used extensively on nursery- or field-sown seed, its effect on growth of tree seedlings needs checking. Information is presented on yearlong growth in the laboratory of seedlings germinated from stratified seed and seed treated with 30 percent H_2O_2.

BACKGROUND

Effects of H_2O_2 on seed germination and seedling development were noticed at least as early as 1908 during work on wheat seed sterilization (Miége 1908). Subsequent sterilization studies on bunt-contaminated wheat seed revealed that germinative energy declined as treatment concentration of H_2O_2 increased (Olgyay 1936). Germinative capacity declined also but to a lesser extent. Weight of wheat plants grown 10 days from seed treated with 15 to 30 percent H_2O_2 ranged from 6 to 33 percent less than weight of plants from untreated seed.

Growth of very young tree seedlings was also reduced by seed treatment in H_2O_2 (Dhillon and Johnson 1962). After 18 to 22 days, hypocotyls of western larch seedlings from seeds treated with 3 percent H_2O_2 for 24 hours were only 42 percent as long as those of seedlings from stratified seeds.

METHODS

Seed from two sources each of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and ponderosa pine (*Pinus ponderosa* Laws.) and one source of western larch (*Larix occidentalis* (Nutt.)) were used. Those seeds serving as a control were soaked in water for 24 hours, surface dried, and stratified in sealed jars for 4 weeks at 34° F. Those given H_2O_2 treatment were taken directly from cold storage and soaked in twice their volume of 30 percent H_2O_2 for 2 hours.

Control and treated seeds were germinated together in a Precision Scientific germinator[1/] operated at 20° and 30° C. for 16 and 8 hours per day, respectively. Seedlings with radicles of similar size from stratified and peroxide treated seeds were then paired and planted in 8-inch clay pots. Four pairs, one from each seed source of Douglas-fir and ponderosa pine, were potted together in each of six pots. Having germinated more slowly, eight pairs of western larch seedlings were later potted together in each of two additional pots. All seedlings were grown on a laboratory bench at room temperature under 16 hours of light daily from fluorescent and incandescent lights. Water was supplied as necessary.

Cotyledon length and length of hypocotyl from cotyledonary node to soil were measured on each 7-week-old seedling. Seedlings were then depotted, and all those with roots still intact were repotted individually in paper containers and grown for an additional 10 months.

[1/] Use of trade names does not constitute endorsement by U.S. Department of Agriculture.

Height growth, needle length, and total dry weight were determined for each year-old seedling. Height was measured from the cotyledonary node to tip of the terminal bud. Individual ponderosa pines burst bud an unequal number of times, so the youngest needles on different plants were not equally mature. For this reason, lengths were measured on the oldest fascicled needles. Measurements were made on Douglas-fir needles located immediately above the cotyledons for the same reason. On western larch, measurements were taken on needles located midway between terminal bud and cotyledonary node where their length seemed to be maximum regardless of seedling height. Weights were determined after seedlings were dried to constant weight at 70° C.

Analysis of variance techniques were used to compare effect of treatment on hypocotyl and cotyledon lengths of 7-week-old seedlings of all three species. Data for 1-year-old western larch seedlings were also subjected to statistical analyses, but due to the small sample, data for Douglas-fir and ponderosa pine were not.

RESULTS

Both hypocotyl and cotyledon length of 7-week-old seedlings from H_2O_2-treated seed tended to be shorter than of those from stratified seed (table 1). The data show a nearly consistent trend,

Table 1.--*Average hypocotyl and cotyledon length of 7-week-old seedlings from stratified and H_2O_2-treated seed*

Species and seed source	Hypocotyl		Cotyledon	
	Stratified	H_2O_2	Stratified	H_2O_2
	Millimeters			
Douglas-fir:				
Wenatchee National Forest	55.5	47.5	26.7	18.7
Mount Baker National Forest	53.3	46.8	28.2	23.8
Both sources	54.4	47.2	27.4	21.2
Ponderosa pine:				
Umpqua National Forest	52.2	43.8	50.8	43.7
Deschutes National Forest	43.2	41.2	48.3	41.7
Both sources	47.7	42.5	49.6	42.7
Western larch:				
Flathead National Forest	20.4	20.5	16.8	16.6

but in only three comparisons was significance demonstrated statistically at the 95-percent confidence level or better. Differences in treatment means for both seed sources together were significant for hypocotyls of Douglas-fir and cotyledons of ponderosa pine, and highly significant for cotyledons of Douglas-fir. Both seed sources of Douglas-fir or ponderosa pine tended to respond similarly to the hydrogen peroxide treatment.

Average size of 1-year-old western larch seedlings from H_2O_2-treated seed was significantly less than those from stratified seed (table 2). Height growth, needle length, and ovendry weight of seedlings from seed treated with H_2O_2 averaged 7.4 centimeters, 1.1 centimeters, and 0.45 gram less, respectively.

In most instances, height growth, needle length, and ovendry weight of year-old Douglas-firs and ponderosa pines from both seed sources also averaged less from peroxide treated seed.

DISCUSSION AND CONCLUSION

Results of this small study support and extend results of earlier laboratory work which showed that H_2O_2 treatment of seed reduced subsequent hypocotyl growth of western larch seedlings (Dhillon and Johnson 1962). Though nursery or field growth of conifer seedlings from H_2O_2-treated seed has not yet been reported, it appears likely that such treatment will adversely affect subsequent growth of some species. Thus, until adverse growth effects can be eliminated, use of H_2O_2 for speeding germination in operational sowings cannot be recommended.

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Table 2.--*Average height growth, needle length, and ovendry weight of 1-year-old seedlings from stratified and H_2O_2-treated seed*

Species and seed source	Seedlings		Height growth		Needle length		Ovendry weight	
	Stratified	H_2O_2	Stratified	H_2O_2	Stratified	H_2O_2	Stratified	H_2O_2
	------*Number*-----		-------------*Centimeters*-------------				------*Grams*------	
Douglas-fir:								
Wenatchee National Forest	3	5	12.9	9.0	1.9	1.6	0.80	0.45
Mount Baker National Forest	4	3	16.2	11.8	2.0	1.9	.99	.71
Ponderosa pine:								
Umpqua National Forest	4	3	10.2	9.3	9.9	9.9	1.30	1.03
Deschutes National Forest	3	3	8.0	7.2	10.4	7.3	1.21	.76
Western larch:								
Flathead National Forest	12	8	19.4	12.0	3.4	2.3	1.06	.61

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A. Forest Service RESEARCH NOTE

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PNW-131 *October 1970*

IPS PINI ATTACK DENSITY IN PONDEROSA PINE THINNING SLASH AS RELATED TO FELLING DATE IN EASTERN OREGON[1]

by

Charles Sartwell
Associate Insect Ecologist

ABSTRACT

Ips pini *attacked 86 percent of the ponderosa pine thinning slash felled during 3 years near Burns, Oreg. Density of attack averaged 10.8 per square foot of bark surface and varied slightly with felling date. Conclusion: Dense attack in slash ordinarily should be expected following precommercial thinnings in eastern Oregon.*

INTRODUCTION

The pine engraver, *Ips pini* (Say)[2] (Coleoptera: Scolytidae), is a major cause of postthinning mortality of ponderosa pine, *Pinus ponderosa* Laws., in eastern Oregon. During the first spring or summer after thinning, beetle populations migrate into residual stands and ordinarily seem to confine their attacks to the thinning slash. However, in warm, dry years they may kill many intended crop trees. In a 3-year study in the early 1940's, Buckhorn[3] found that more than 95 percent of ips-caused mortality in recently logged stands occurred where cuttings had been made from February through July. When thinning programs were begun in east-side forests during the 1950's, he recommended that thinnings be scheduled to avoid the "hazardous" February-July period. But, by the early 1960's, such extensive acreages were being treated that many land managers found it very difficult to restrict thinnings to the "safe" months of August to January, and they requested information on how to thin safely during the hazardous months. This study aimed toward explaining the association of damage hazard with date of thinning or slash deposition and was a test of the hypothesis that this hazard is directly related to density of *Ips pini* attack in the thinning slash.

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[1] Part of Master of Science thesis, University of Idaho, Moscow.

[2] This insect was known in the Western United States as the Oregon pine ips, *Ips oregoni* (Eichhoff), until a recent generic revision by Hopping (1964).

METHODS

This study was conducted in the Malheur National Forest, about 40 miles north of Burns and about 80 miles east of where Buckhorn studied. According to Dolph,[4] this area is within a zone of high outbreak frequency. Severe tree killing was extensive here in the summer of 1962,[5] but only scattered, endemic killing occurred during the years of study. Data were collected at elevations ranging from 4,700 to 5,400 feet.

Ips pini has two generations per year in the study area.[6] Overwintering adults emerge and attack in April or May. The first generation subsequently emerges and attacks during midsummer. The second generation overwinters and does not fly until the subsequent spring. In this locality, slash felled after early August is seldom attacked in the same calendar year, but some earlier felled materials may be attacked as late as early September.

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[3] W. J. Buckhorn. Preliminary report on the relation of logging operations to outbreaks of *Ips oregoni* in ponderosa pine forests. Unpublished report on file at Pacific Northwest Forest & Range Experiment Station, Portland, Oreg. July 8, 1942.

[4] R. E. Dolph, Jr. Summary of Oregon pine ips damage in the Pacific Northwest from 1952 to 1962, and suggested measures for preventing outbreaks in young ponderosa pine stands. Division of Timber Management, Pacific Northwest Regional Office, USDA Forest Service, Portland, Oreg. April 1965.

[5] D. G. Mook. *Ips* infestation analysis. Unpublished report, Division of Timber Management, Pacific Northwest Regional Office, USDA Forest Service, Portland, Oreg. Feb. 25, 1963.

[6] C. Sartwell, Jr. Mountain pine beetle and Oregon pine ips: progress report on 1963 exploratory studies. Unpublished report on file at Pacific Northwest Forest & Range Experiment Station, Portland, Oreg. Aug. 1, 1964.

The sampled slash was felled in operational, precommercial thinnings in the 3-year period from August 1962 to July 1965. Approximately 2,000 acres were thinned to a 12- by 12-foot spacing, which resulted in about 500 to 800 felled trees per acre. Most trees up to 5.5-inch d.b.h., occasionally a few larger, were cut and left where felled.

A plot consisted of slash felled in a particular month and year, and slash was available for 32 of the possible 36 months. Sampling for density of attacks was done 1 year after felling when the slash was either abandoned by *Ips pini* or presumably no longer attractive to it. The sampling unit was a 1-foot-long bolt cut from the trunk of a slash tree at what had been 4 to 5 feet above ground level before felling. To select slash trees for samples, a string line was laid in a cardinal direction across the approximate middle of the plot; and, starting 100 feet into the plot, every 10th felled tree crossed by this line was sampled. Ten samples were taken from each plot for a grand total of 320. The sample bolts were brought to a laboratory, where the bark was completely removed and the attacks (nuptial chambers) were counted.

No quantitative data about tree mortality were obtained, as the study intent was to relate density of attack in slash with the mortality hazard to residual trees as established by Buckhorn's findings.

RESULTS

The pine engraver attacked 86 percent of the sampled slash trees, which is similar to attack in 80 percent of the ponderosa pine logging slash studied by Buckhorn in the nearby Ochoco National Forest. But Schenk et al. (1957) found that only 60 and 21 percent of the slash was infested by *Ips pini* after two precommercial thinnings of jack pine in Wisconsin, and McComb (1955) reported that about 30 to 65 percent of Engelmann spruce (*Picea engelmannii* Parry) trap trees in Montana were attacked by this beetle.

Mean density of attack per square foot of bark surface was 10.8 for all samples and 12.6 for only the attacked samples. These values are about three times greater than Reid (1957) found in lodgepole pine (*Pinus contorta* Dougl.) slash in the Canadian Rocky Mountains but are similar to those in selected pieces of heavily attacked slash reported by Cameron and Borden (1967) for *Ips confusus* (LeConte) in ponderosa pine in California and by Mason (1965) for the combination of *Ips avulsus* (Eichhoff) and *Ips grandicollis* (Eichhoff) in loblolly pine in Tennessee. In short, a rather large *Ips pini* population was present in the study area.

Contrary to the original study hypothesis, attacks were not densest in slash felled in the hazardous months. Rather, as shown in table 1, they averaged slightly higher in thinning debris deposited in the safe August-January months. However, this difference was due mainly to variation within the year 1963-64, when attacks in safe slash were nearly three times as dense as in materials felled in the hazardous February-July months. In the other two seasons, density of attacks was not significantly different between safe and hazardous slash.

Table 1.--*Mean* Ips pini *attacks per square foot of bark surface by group of felling months*

Felling month group	Year slash felled			3 years
	1962-63	1963-64	1964-65	
Aug.-Jan. (safe)	16.7	15.9	6.2	12.5
Feb.-July (hazardous)	14.2	6.2	7.5	9.1
Difference	(1/)	**	(1/)	*

* Difference statistically significant at 95-percent level.
** Difference statistically significant at 99-percent level.
1/ Not significant.

As is evident in table 2 and figure 1, there was some indication of a trend toward two peaks in the relation of density of attack to particular month of felling. This suggests that, at time of main beetle flight both in the spring and midsummer, some available slash probably was too old and some was too fresh for maximum attraction of attacking beetles. However, as indicated by the wide 95-percent confidence intervals for the 3-year means, density of attacks was too variable within months and between years to confirm this trend. Notwithstanding this variability, the data in table 2 and figure 1 confirm those in table 1 in showing that the slash felled in the hazardous months of February through July was not attacked more densely than that felled in the safe months of August through January.

DISCUSSION

The findings here do not explain why *Ips pini* is more likely to kill residual trees following February-July thinnings than after August-January treatments. But they do indicate that, in current operational thinning situations, the difference in damage hazard is not directly related to abundance of attacking beetles. Theoretically, of course, Table 2.--*Mean* Ips pini *attacks per square foot of bark surface as related to particular month of felling of ponderosa pine thinning slash*

Month slash felled	Year slash felled			3 years	95-percent confidence intervals
	1962-63	1963-64	1964-65		
Aug.	12.4	8.1	1.6	7.4	5.0- 9.8
Sept.	14.8	--	3.1	9.0	5.0-13.0
Oct.	--	20.0	4.4	12.2	6.5-17.9
Nov.	18.5	18.2	6.4	14.4	10.6-18.2
Dec.	25.5	13.9	10.7	16.7	12.8-20.6
Jan.	12.5	19.2	10.8	14.2	11.1-17.3
Feb.	8.3	5.9	10.6	8.3	6.1-10.5
Mar.	14.7	6.7	6.6	9.3	6.7-11.9
Apr.	--	6.3	8.4	7.3	4.6-10.0
May	10.8	7.5	4.8	7.7	4.8-10.6
June	22.1	7.8	7.0	12.3	8.8-15.8
July	15.2	3.2	--	9.2	5.4-13.0
Year	15.5	10.6	6.8	10.8	9.8-11.8

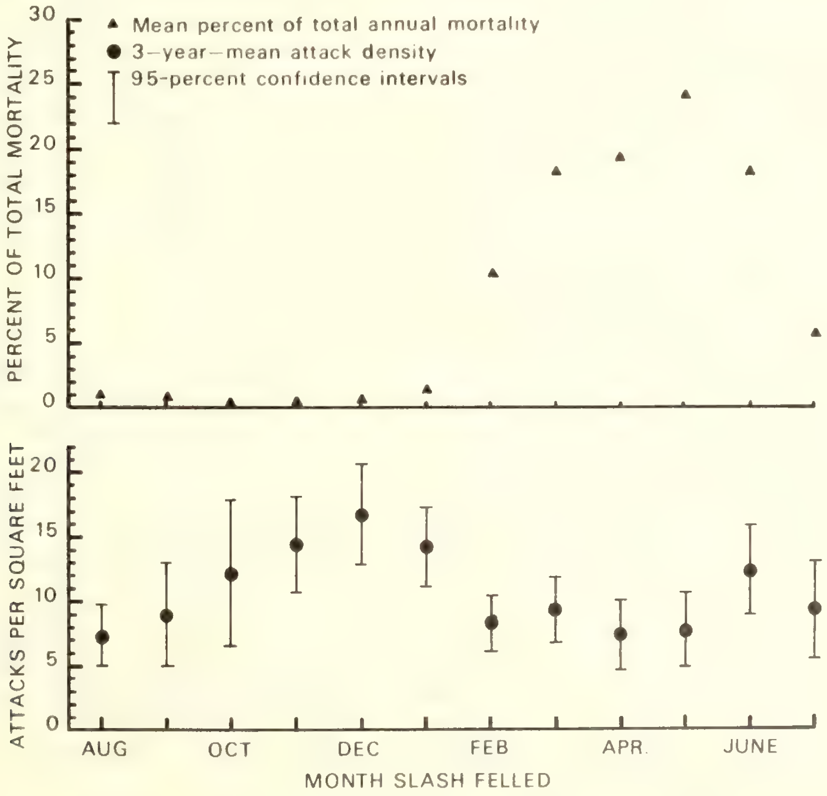

Figure 1.--Tree mortality caused by *Ips pini* (unpublished data from Buckhorn) and attack density in thinning slash as related to month of thinning or felling.

a large beetle population is one prerequisite to the occurrence of severe tree mortality. But in the study area, which is typical of much of eastern Oregon, beetles are so generally abundant that this prerequisite is usually met.

For further understanding of why damage probability is associated with felling date, it is necessary to clarify whether tree killing occurs predominantly when beetles are migrating into a stand to attack the slash or while newly emerged beetles are abandoning the slash in which they developed. Circumstantial and observational evidence strongly indicate that, as Person reported (see Keen and Craighead 1927) for western pine beetle, *Dendroctonus brevicomis* LeConte, the great bulk of the killing by *Ips pini* occurs while the slash is under attack, rather than when beetles bred in the slash are emerging from it. During this study it was observed that beetles emerging from overwintering sites attacked mainly in August-January slash. Wygant and Rodriguez-Lara (1967) have pointed out that tree killing by these spring-flying beetles rarely reaches pest problem proportions. It is also evident from Buckhorn's findings that the first generation adults cause very little killing in the stands where they develop. Because the second generation does not fly until after overwintering, it is clear that tree killing occurs mainly in midsummer while the first generation adults are migrating into new slash areas--mostly stands where slash was felled from February through July.

The studies of Vité (1961) and Stark (1965) indicate that ponderosa pine resistance to attack by bark beetles generally is highest in the spring and declines through the summer. Thus, one explanation of the higher ips-caused mortality associated with February-July thinnings is that *Ips pini* migration into these stands during midsummer occurs at a time when residual tree resistance to attack is relatively low. Conversely, mortality is lower in stands thinned August-January because attacking beetles invade these stands in the spring when tree resistance is higher.

Another explanation, perhaps complementary to the preceding, is that capacity of *Ips pini* populations to overcome trees may be greater in midsummer than in the spring because attacking beetles concentrate more rapidly in warm weather than in cool. Although similar numbers of beetles may invade two comparable stands, the threat to residual trees would be greater where beetle migration is concentrated in time than where it is protracted. Mason (1970) suggests that in the Southern United States the more rapid aggregation of *Ips avulsus* (Eichhoff) partly explains why it is a more important tree killer than *Ips grandicollis* (Eichhoff), which does not aggregate as rapidly when attacking. Thus, rapid aggregation of beetles would seem a prerequisite to tree killing by *Ips* bark beetles, and the hypothesis here is that this is more likely to occur in midsummer than in spring.

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DIGITIZING TOPOGRAPHIC DATA FOR SKYLINE DESIGN PROGRAMS

by

Ward W. Carson, Donald D. Studier, and William M. Thomas[1]

ABSTRACT

Presents a procedure for digitizing skyline road topographic data from stereo-aerial photographs. A Kelsh-type stereoplotter and digital scaler are used to prepare computer data cards. Will be helpful to the designer who uses large digital computers for skyline road design.

1.0 INTRODUCTION

Several computer programs have been or are being written to aid forest engineers in the layout of skyline logging shows.[2] These skyline design programs were developed to compute load-carrying capability under a variety of topographic conditions and equipment. Collecting topographic data from the ground, contour maps, or photos requires a significant effort when several skyline roads are involved. This note discusses a procedure for the collection of topographic data from stereophotographs through use of a Kelsh-type stereoplotter[3] and a digital scaler or digitizer. The operator procedures and card formats are presented to insure compatibility between computer program input and the stereoplotter digitizer output.

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[1] The authors are, respectively, research mechanical engineer, Forest Engineering Research, Pacific Northwest Forest and Range Experiment Station, Seattle, Wash.; civil engineer, Gifford Pinchot National Forest, Vancouver, Wash.; and photogrammetrist, Division of Engineering, Region 6, Portland, Oreg. All are with Forest Service, U.S. Department of Agriculture.

[2] Skyline design programs SKY16 and RSKY, written by the Forest Engineering Project, Pacific Northwest Forest and Range Experiment Station, Seattle, Wash. These programs are written in Fortran IV and are presently operational on the CDC 3100 computing facilities in main office, USDA Forest Service, Region 6, Portland, Oreg.

Briefly, the skyline designer prepares equipment information and specific road descriptions on photographs. The stereoplotter operator, through use of the digitizer and keypunch, takes terrain point data directly from the stereophotograph model and prepares data cards describing each skyline road. The format of these cards is compatible with the skyline design programs and is ready for direct use. The purpose of this note is to discuss the responsibilities of the designer, plotter operator, and data processing personnel in the total procedure for digitizing the skyline design information. The following sections discuss separately the responsibilities of each of these individuals.

2.0 PREPARATION OF DATA--DESIGNER

The procedures for planning a skyline sale are discussed by Binkley and Lysons in "Planning Single-Span Skylines."[4] The designer must provide equipment information and geometric data for each skyline road. The geometric data include the height and location of the headspar and tailspar, the location of the inner and outer yarding limits, the carriage ground clearance, and the terrain profile data.

The information must be submitted in a format that will be accepted by the stereoplotter and the skyline design programs. The title data, equipment data, height of headspar and tailspar, and clearance are submitted on the forms illustrated in figure 1 for the standing skyline and figure 2 for the running skyline. The input form is accompanied by aerial photographs with the skyline roads delineated (fig. 3).

The input data for both skyline design programs are basically the same. The numbers in the upper right-hand corner of each block on the input form indicate the column number on the data card. For example, there are 70 spaces allowed for the project title and 10 spaces for the date.

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[3] Mention of products by name does not constitute endorsement by the U.S. Department of Agriculture.

[4] Virgil W. Binkley and Hilton H. Lysons. Planning single-span skylines. Pacific Northwest Forest & Range Exp. Sta. USDA Forest Serv. Res. Pap. PNW-66, 10 pp., illus. 1968.

Project title: 70	Date: 80

Region: 10	Forest: 30	District: 50	Location: 80

EQUIPMENT DATA

SKYLINE			MAIN LINE				
Cable diameter	Cable weight	Breaking strength	Cable diameter	Cable weight	Breaking strength	Safety factor	Carriage weight
10 xx.xx	20 xxx.xx	30 xxxxxx.xx	40 xx.xx	50 xx.xx	60 xxxxxx.xx	70 x.xx	80 xxxx.xx
.	.	.	.	.	.	.	.

Number of skyline roads 25	Number of critical points to be examined on each skyline road 60	Format of geometric input data 80

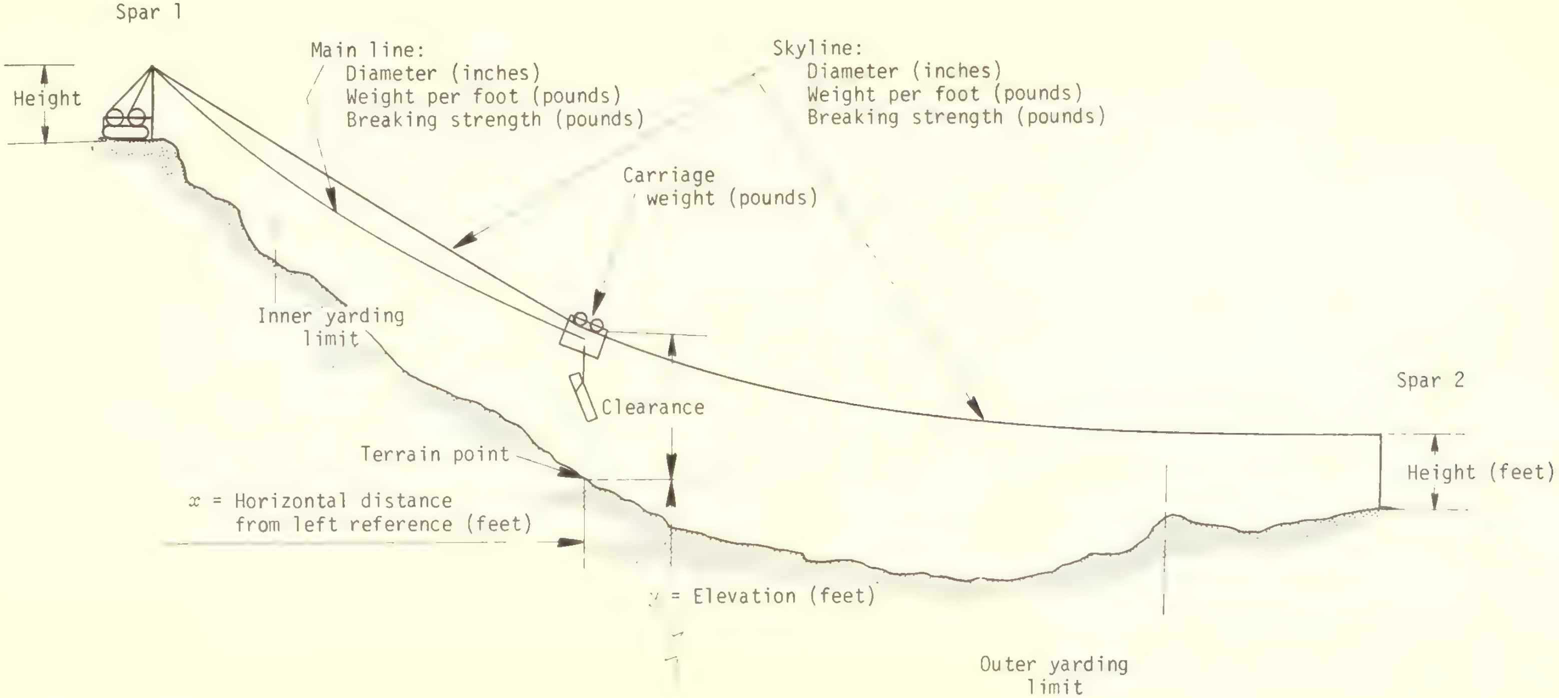


Figure 1.–Standing skyline.

RUNNING SKYLINE

Project title:			70
Date: 80			
Region: 10	Forest: 30	District: 50	Location: 80

EQUIPMENT DATA

HAULBACK			MAIN LINE				
Cable diameter	Cable weight	Breaking strength	Cable diameter	Cable weight	Breaking strength	Safety factor	Carriage weight
10 xx.xx	20 xxx.xx	30 xxxxxx.xx	40 xx.xx	50 xx.xx	60 xxxxxx.xx	70 x.xx	80 xxxx.xx
.	.	.	.	.	.	.	.
Number of skyline roads 25						Format of geometric input data 80	

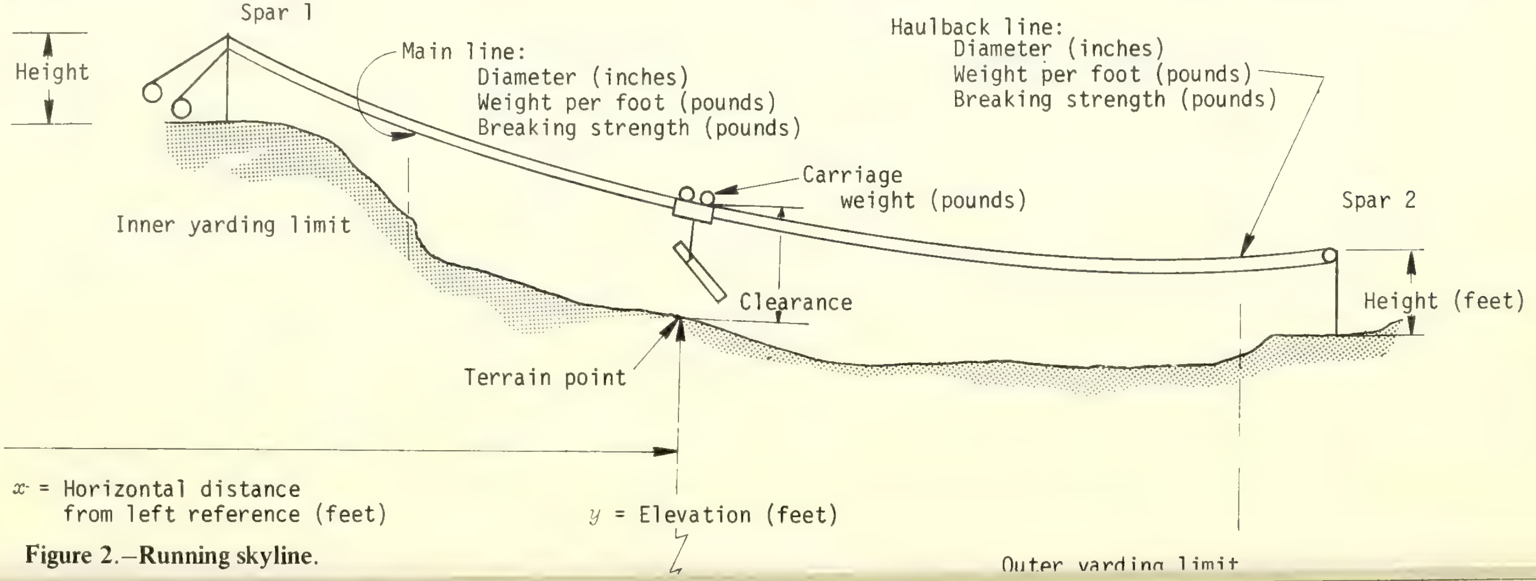
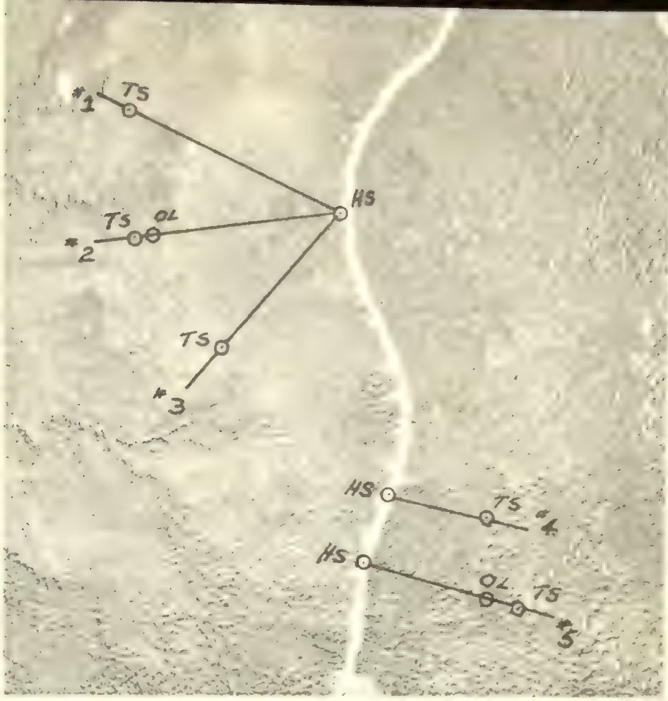


Figure 2.—Running skyline.

Figure 3.–Aerial photograph positive prepared by the designer.



The last line under "Equipment Data" is for indicators which are used internally by the design programs. These indicators are:

1. Number of skyline roads: the number of skyline roads delineated on the aerial photograph. Each skyline road is described by one set of geometric data.
2. Format of geometric input data: this indication is coded 1 if the terrain data are to be taken from aerial photographs by the procedures discussed in this note.

The height of the headspar, tailspar, and the carriage ground clearance should be indicated in the space provided in the figure.

The aerial photos should include the following information:

1. Each skyline road that is to be investigated must be delineated on the photo and numbered.
2. The locations of the headspar and tailspar for each road should be pinpricked, circled, and labeled HS and TS, respectively.
3. The inner and outer yarding limits, if different from HS and TS, should be circled and labeled IL and OL, respectively.

The lines and labeling are done with transparent, india-type (waterproof), vermilion ink to avoid obscuring details on the photographs (fig. 3).

3.0 OPERATIONAL PROCEDURE--PLOTTER OPERATOR

The stereoplotter operator can prepare the data cards describing the skyline equipment and each skyline road. The general information and equipment specifications are keypunched onto data cards directly from figure 1 or 2 as presented by the designer. The terrain point data are prepared by a Kelsh plotter-digitizer-keypunch system, as discussed in this section.

Glass plates of the photographs submitted by the designer are set up as a stereomodel on the Kelsh plotter, leveled, and scaled to best available control. An individual skyline road, as prepared on the photograph positive by the designer, will appear on the Kelsh plotter manuscript. From the stereomodel, through the digitizer and keypunch, the operator will prepare a lead card and a series of terrain point cards. A definition of the data and card format is discussed in section 4.0. This section should be referenced for definition of terms, data format, and programing of the digitizer. The plotter operator procedure for preparing lead card and terrain point cards for each skyline road is discussed here.

Preparing lead card:

Step 1. Using constants on the digitizer, set up the road number, carriage clearance, headspar height, tailspar height, and card indicator information (format in section 4.0).

Step 2. Locate the headspar, set indicator at 1, and record.

Step 3. Locate the inner yarding limit, set indicator at 1, and record.

Step 4. Locate the outer yarding limit, set indicator at 1, and record.

Step 5. Locate the tailspar, set indicator at 1, and record.

After the lead card is complete, return to start of skyline road to prepare for generating terrain point cards.

Preparing terrain point cards:

Step 1. Reset the card indicator constant on the digitizer to 2.

Step 2. Beginning at the first terrain point, record all prominent terrain points, using a point indicator of 2. On the last terrain point, use a point indicator of 3.

This completes the description of a skyline road. The procedure is repeated for each skyline road in the total layout. These data cards are then placed behind the data cards prepared from figure 1 or 2, and the set can then be submitted for processing by the skyline design computer programs.

4.0 DATA FORMAT--PROCESSING PERSONNEL

To insure compatibility between the skyline design computer programs and the data input prepared by this procedure, the required information and computer data cards are thoroughly discussed. The patch panel design necessary on an Auto-trol Model 3700 digitizer and the control panel design are shown.

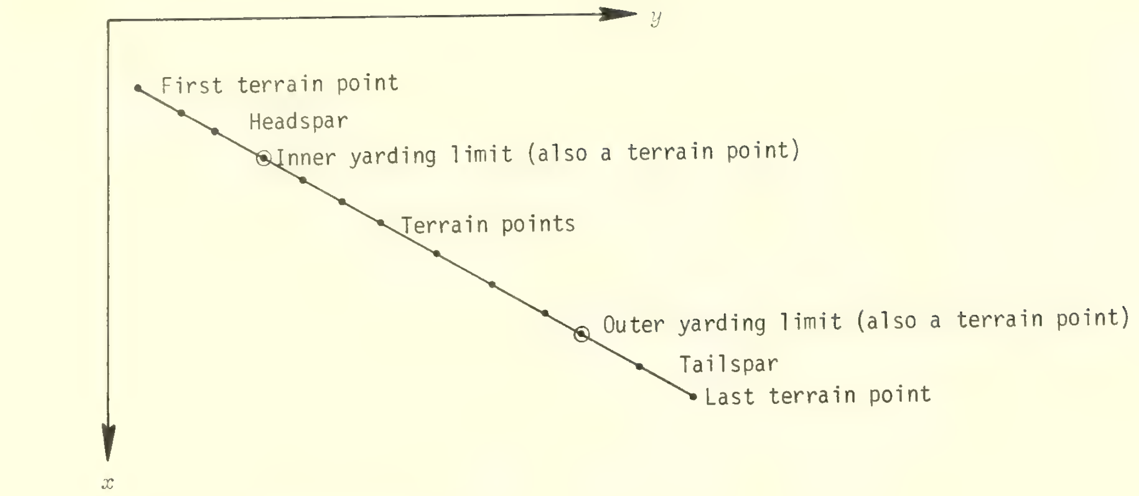
Required information.--A complete description of a skyline road for input to the computer program requires the following information (fig. 4):

Constants:

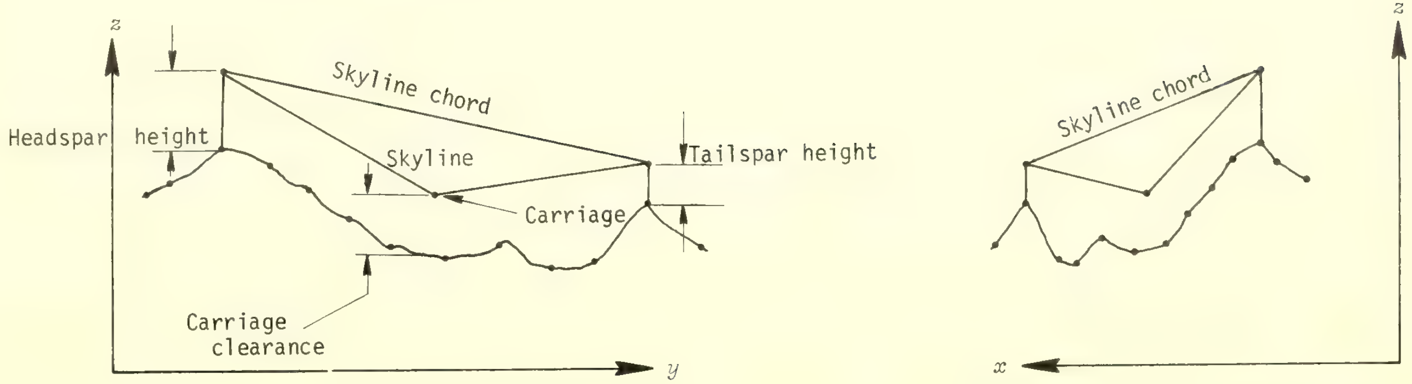
Road number	An integer used to identify skyline roads.
Carriage clearance, feet	The vertical distance between carriage and ground required at each terrain point.
Headspar height, feet	The vertical height of the headspar above ground.
Tailspar height, feet	The vertical height of the tailspar above ground.

Locations indicated on the photo:

Headspar location, feet	The (x,y,z) coordinates of the headspar location.
Inner yarding limit, feet	The (x,y,z) coordinates of the inner yarding limit of the skyline road.
Outer yarding limit, feet	The (x,y,z) coordinates of the outer yarding limit of the skyline road.
Tailspar location, feet	The (x,y,z) coordinates of the tailspar location.
Intermediate terrain points	The (x,y,z) coordinates of the prominent terrain points on the skyline road.


y
First terrain point
Headspar
Inner yarding limit (also a terrain point)
Terrain points
Outer yarding limit (also a terrain point)
Tailspar
Last terrain point
x

xy - Plan view (photo)



yz - Elevation view

xz - Elevation view

Figure 4.–Skyline road geometry.

The designer provides the stereoplotter operator with the constants and the locations indicated on photos for every skyline road. The operator can record this information on data cards through the constant-input knobs and the automatic digitizing features of the digital scaler. The format of these cards and the procedure for developing them are presented here.

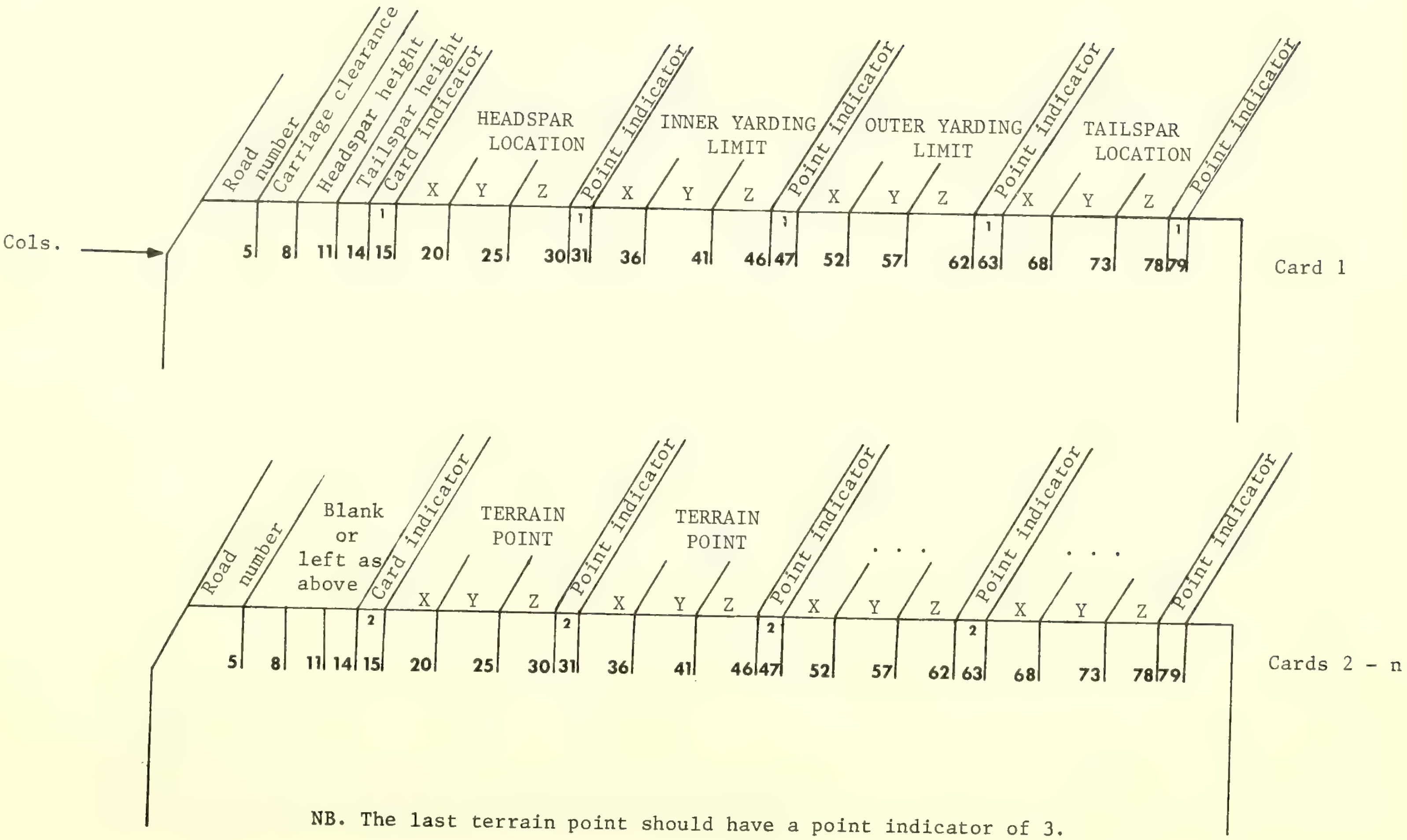
Format.--The required information will be digitized onto one lead card (fig. 5) and as many additional cards as are required to record the intermediate terrain point data. The lead card is arranged as follows (all numbers are right-adjusted integers):

		Columns
Constants: Entered via manual selectors	-Road number	1 - 5
	-Carriage clearance	6 - 8
	-Headspar height	9 - 11
	-Tailspar height	12 - 14
	-Card indicator (set = 1)	15
Locations, (x,y,z) coordinates, and point indicators; automatically recorded	-Headspar location	16 - 31
	-Inner yarding limit	32 - 47
	-Outer yarding limit	48 - 63
	-Tailspar location	64 - 79

The cards following the lead card are used to record intermediate terrain point coordinates. Four sets of (x, y, z) information along with point indicators can be accommodated per card. The first 15 columns, recorded manually on the lead card, can be left the same, except the card indicator in column 15. This should be reset to 2. The point indicators on all intermediate terrain points should be recorded as 2, except the last point. This one should be entered as 3. The format of these terrain cards will be as follows:

		Columns
Constants:	-Road number, carriage clearance, headspar and tailspar height, as in lead card.	1 - 14
	-Card indicator (set = 2)	15
Locations, (x,y,z) coordinates, and point indicators; automatically recorded.	-Starting at first terrain point, record all points in sequence toward tailspar. Use as many cards as are required, and use a point indicator of 3 to indicate the last terrain point.	16 - 79

Figure 5.–Digitizer card format.



NB. The last terrain point should have a point indicator of 3.

Auto-trol Model 3700 Patch Panel

Preparation of the (x,y,z) coordinates by the digitizer into the desired format requires programing. If an Auto-trol Model 3700 digitizer is used, this programing is accomplished with a patch panel as shown in figure 6.

The connections required on this patch panel are given in table 1.

Auto-trol Model 3700 Control Panel

If an Auto-trol Model 3700 digitizer is used, the road number, carriage clearance, headspar height, and tailspar height will be entered through digital constant knobs on the control panel. The control panel is shown in figure 7.

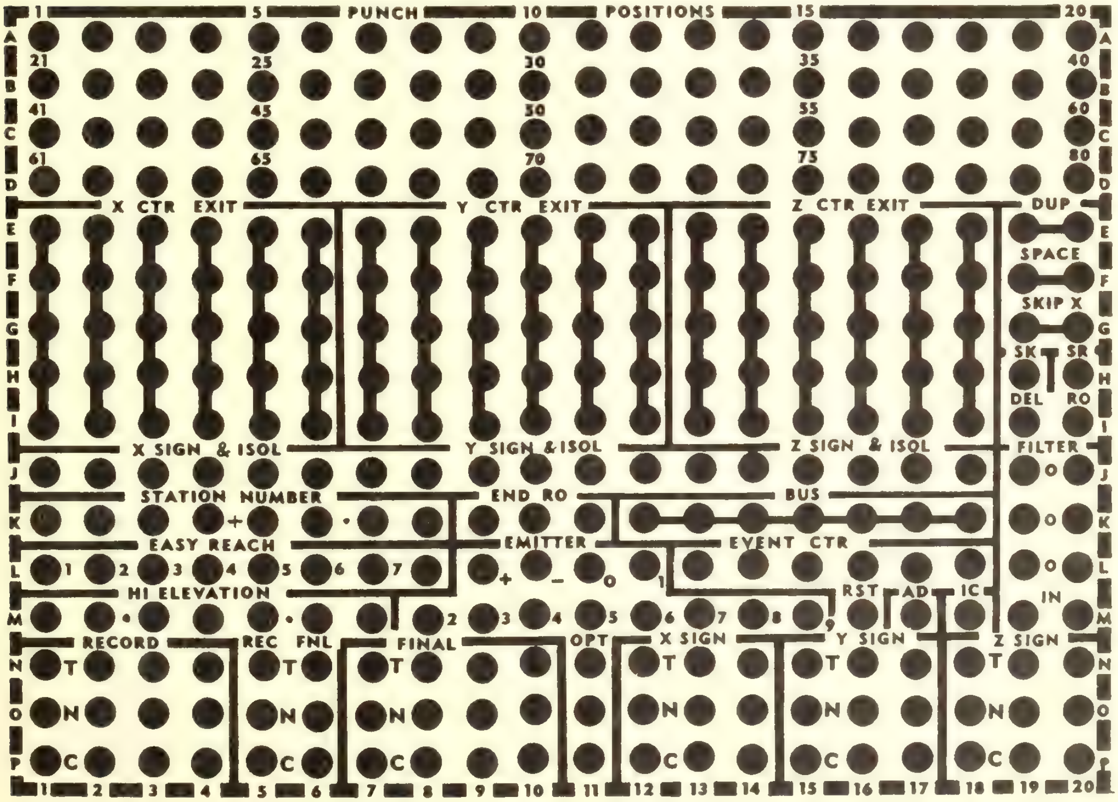


Figure 6.—Auto-trol Model 3700 patch panel.

Table 1.--*Patch panel connections*

Column	is connected to:	Column	is connected to:
1	P1	45	F17
2	N2	46	F18
3	M19	47	K16
4	K4	48	G2
5	K5	49	G3
6	K6	50	G4
7	K7	51	G5
8	K8	52	G6
9	M1	53	G8
10	M2	54	G9
11	M3	55	G10
12	M4	56	G11
13	M5	57	G12
14	M6	58	G14
15	K18	59	G15
16	E2	60	G16
17	E3	61	G17
18	E4	62	G18
19	E5	63	K15
20	E6	64	H2
21	E8	65	H3
22	E9	66	H4
23	E10	67	H5
24	E11	68	H6
25	E12	69	H8
26	E14	70	H9
27	E15	71	H10
28	E16	72	H11
29	E17	73	H12
30	E18	74	H14
31	K17	75	H15
32	F2	76	H16
33	F3	77	H17
34	F4	78	H18
35	F5	79	K14
36	F6	80	F20
37	F8	K13	M7
38	F9	P10	G20
39	F10	N10	H19
40	F11	P5	J12
41	F12	K3	L19
42	F14	P2	K2
43	F15	N1	K1
44	F16	K10	J18

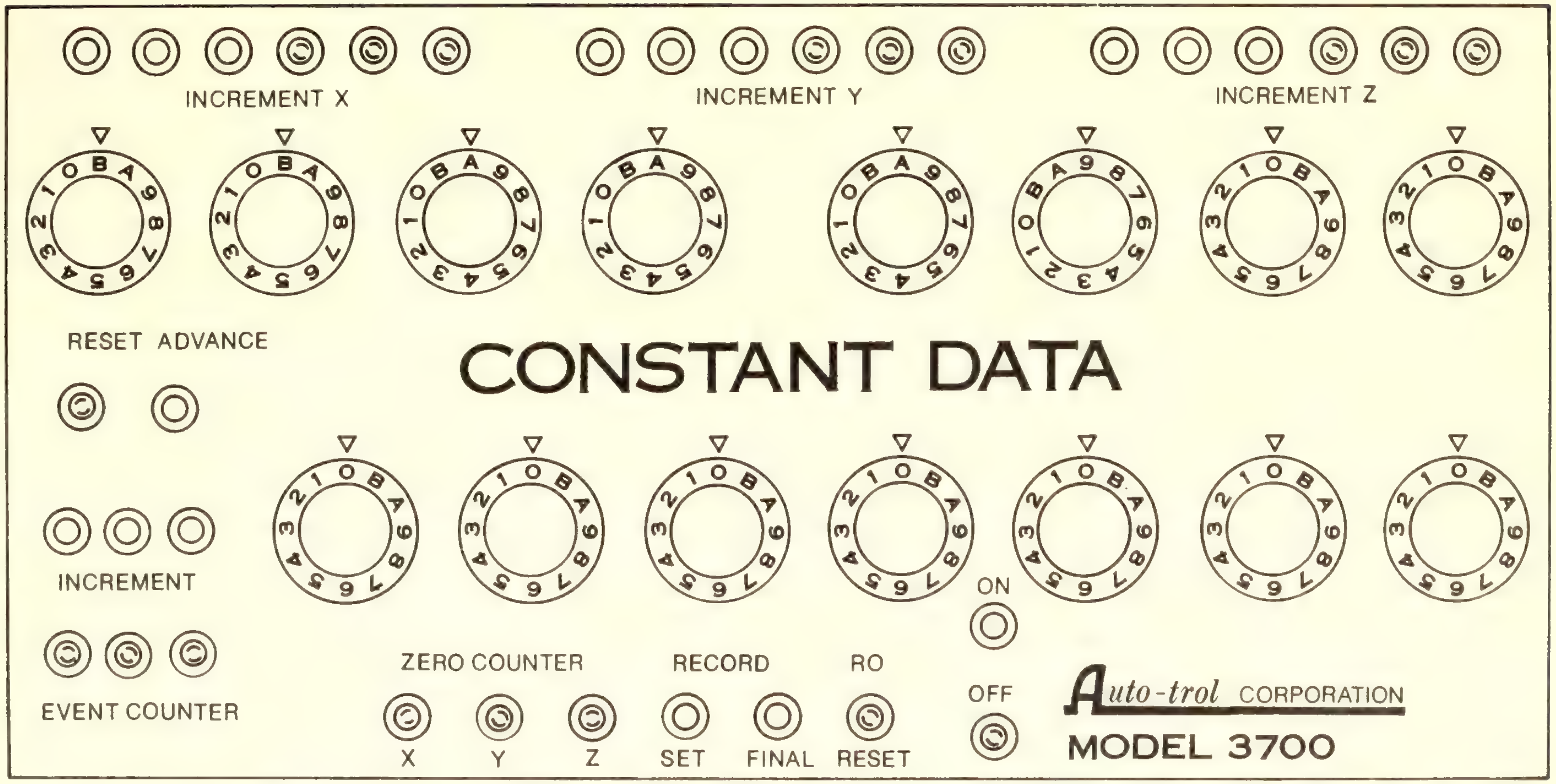


Figure 7.—3700 control panel.

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A. Forest Service RESEARCH NOTE

PNW-133 November 1970

SURVIVAL AND GROWTH OF BITTERBRUSH ON THE SILVER LAKE DEER WINTER RANGE IN CENTRAL OREGON

by

J. Edward Dealy, *Associate Plant Ecologist*

ABSTRACT

A 4-year-old bitterbrush plantation is being watched for response to browsing protection and release from competing vegetation. After 2 years, response is greater from browsing protection than from elimination of plant competition and shows up more in crown size than in plant height.

INTRODUCTION

This report presents results of the first 2 years of our study on survival of planted bitterbrush (*Purshia tridentata*)[1] and its response to browsing protection and release from competing vegetation in central Oregon. The questions we hope to answer at the conclusion of the study are (1) Can we expect a young stand of planted bitterbrush to survive and develop into an adequate forage supply for deer under persistent heavy winter browsing? and (2) How are survival and growth affected by the elimination of plant competition and/or animal use?

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[1] The source for scientific nomenclature is C. Leo Hitchcock, Arthur Cronquist, Marion Ownbey, and J. W. Thompson. Vascular plants of the Pacific Northwest. Seattle, Univ. Wash. Press, 5 vols., 1955.

Ferguson,[2] studying growth and survival of planted bitterbrush in Idaho over a 9- to 15-year period, found in one area 20 percent greater shrub survival under no browsing compared with moderate deer use. In another area under similar conditions, he found no difference in survival. In nearly all cases, protected shrubs had crowns 1½ to 3½ times larger than browsed ones. All plantings were made in scalped areas, so competing vegetation was not a factor.

THE STUDY AREA

The study area is in a bitterbrush seeding of 20 acres in the upper part of a mule deer winter range in the Silver Lake Valley of central Oregon. It is located about one-half mile outside the timbered edge of the summer range at 4,700-foot elevation in rolling topography. Soil is a moderately deep, well-drained sandy loam.

The bitterbrush plantation was seeded by rangeland drill and was part of a 2,500-acre burn aerially seeded to crested wheatgrass. Bitterbrush had been an important component of the stand before the burning.

The current primary shrub cover includes bitterbrush, big sagebrush (*Artemisia tridentata*), green rabbitbrush (*Chrysothamnus vicidiflorus*), and gray rabbitbrush (*C. nauseosus*). Grasses include crested wheatgrass (*Agropyron cristatum*), bluebunch wheatgrass (*A. spicatum*), Idaho fescue (*Festuca idahoensis*), bottlebrush squirreltail (*Sitanion hystrix*), and Thurber stipa (*Stipa thurberiana*). Some common forbs are lupine (*Lupinus* sp.), hoary chaenactis (*Chaenactis douglasii*), salsify (*Tragopogon* sp.), buttercup (*Ranunculus* sp.), aster (*Aster* sp.), and milk vetch (*Astragalus* sp.).

Annual precipitation is approximately 11 inches, of which 40 percent falls during the winter, 50 percent during the spring and fall periods, and 10 percent during the summer.

Since the study began, removal by foraging on the area has been primarily by mule deer. There has been some use by rodents and occasional trespass by sheep; however, it is minor and considered unimportant as an influence on the study. Removal by foraging on bitterbrush is approximately 70 percent each winter.

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[2] Robert B. Ferguson. Survival and growth of young bitterbrush browsed by deer. J. Wildlife Manage. 32:769-772, 1968.

METHODS

Eighty 4-year-old plants were selected from the survivors of the original seeding. Of these, 20 were chosen at random for each of the following treatments:

1. Caged and vegetation competition
2. Caged and no vegetation competition
3. Uncaged and vegetation competition
4. Uncaged and no vegetation competition

Forty plants were caged individually with a circle of heavy 4-foot welded wire fence, and 40 were left open. Half of both the caged and uncaged plants were cleared each year of competing vegetation to a radius of 3 feet.

Random sampling using milacre plots for density was conducted throughout the 20-acre seeding to determine establishment and stocking success for the entire plantation during the first 6 years.

Total plant height, including current growth, was measured to the nearest one-tenth foot on each plant each year after growth had been completed. The widest and narrowest crown diameters were used to calculate the area of an ellipse expressed as square feet of crown cover. Differences in total plant height and crown cover were analyzed in a completely randomized 2 by 2 factorial by analysis of variance for the following treatment combinations: caged vs. uncaged, released vs. unreleased, and the interaction of caged plus released.

RESULTS

Establishment and survival success of the 20-acre plantation has been relatively poor. Twenty random samples of 20 plots each showed an average density of 260 plants per acre. This amounts to about 13-foot spacing, a level which indicates a poorly stocked stand. Emor Nord[3/] found in California that good stands of bitterbrush averaged 700 to 800 plants per acre.

All 80 study plants survived through the first 2 years. However, two plants that were obviously weak have recently died. These plants were both in the treatment "uncaged and no vegetation competition." It must be realized that this is mortality from a choice crop of plants which were picked after the 20-acre plantation had had four growing seasons to weed out the weak plants.

[3/] Emor C. Nord. Bitterbrush ecology--some recent findings. USDA Forest Serv. Pac. Southwest Forest and Range Exp. Sta. Res. Note 148, 4 p., 1959.

Measurements made 2 years after treatment (two seasons of accumulated growth) showed that shrub height and crown cover responded somewhat differently as shown in figure 1. For height, there was a highly significant response to protection from browsing, averaging 0.7 foot per plant; a significant, though very small response to release from plant competition, averaging 0.1 foot per plant; and no significant interaction effect of the two.

On the other hand, the response of crown cover was highly significant in all cases. Not only were the treatments and interaction responses highly significant, but the differences in treatment means were startling after only two growing seasons. Protection from browsing

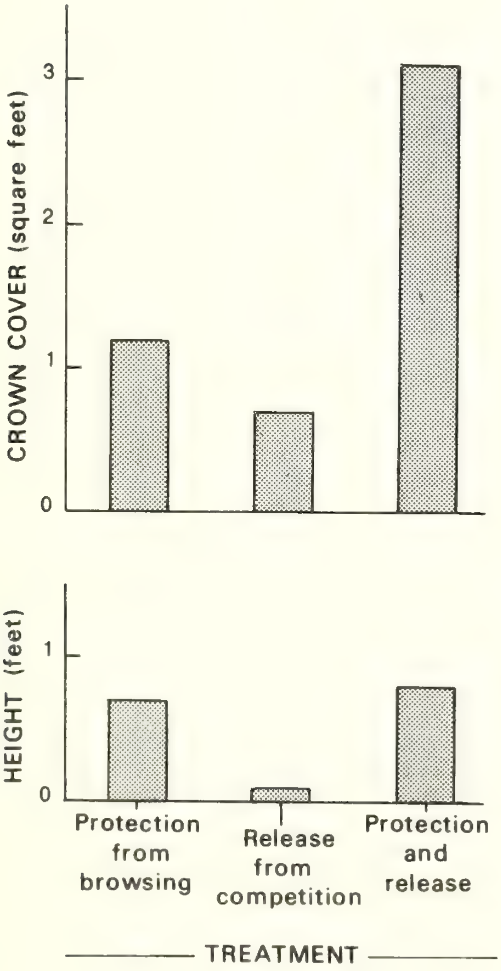

Figure 1.--*Average response per plant of an established antelope bitterbrush planting after 2 years of protection from deer browsing, vegetation competition, and the two combined. Values are for two seasons of accumulated growth.*

resulted in an average increase of 1.2 square feet per plant, and release from vegetation competition produced an average increase of 0.7 square foot. The response especially outstanding was the combination of vegetation release and protection from browsing--an average increase of 3.1 square feet per plant, including a 1.2-square-foot interaction effect.

Although it is too early to draw conclusions from these responses, a few observations are in order: (1) establishment of an adequately stocked plantation (700-800 plants per acre) may well be as much of a problem as subsequent development of the plants for maximum forage production, (2) crown cover showed a greater response to all treatments and combination of treatments than did plant height, and (3) protection from browsing was the most important single treatment for both crown cover and height--responses were 50 percent greater than release from competing vegetation.

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A. Forest Service RESEARCH NOTE

CLEMSON UNIVERSITY
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PNW-134 *November 1970*

ESTIMATE OF DRY VENEER VOLUME LOSSES
IN DOUGLAS-FIR PLYWOOD MANUFACTURE

by

Douglas L. Hunt, *Forest Products Technologist*
Timber Management, Region 6

and

Richard O. Woodfin, Jr., *Wood Technologist*
Pacific Northwest Forest and Range Experiment Station

ABSTRACT

The factors presented in this report will aid the mill operator in estimating his losses of dry Douglas-fir veneer during plywood panel production. The total loss from dry veneer to trimmed panels is 16 percent. Techniques applied in the study can be used by a plywood mill to conduct similar tests and compare their results with those presented in this report.

INTRODUCTION

This report presents factors for estimating the loss of dry veneer in manufacturing plywood. The losses were measured at plywood production operations between the veneer dryer and the panel press. The factors were developed from volume loss studies at three Oregon-Washington veneer mills peeling coast type Douglas-fir.

Veneer mill production is usually expressed in terms of a given veneer thickness. The most accepted expression is square feet of veneer on a 3/8-inch basis. Factors are available that will convert a single veneer thickness to the 3/8-inch basis.

The loss factors in this report will aid the mill operator in estimating his recovery of dry Douglas-fir veneer for panel production. The volume of veneer pulled out of the dryer and stacked can be expressed in terms of final volume that will be available for layup. The factors presented here can be applied to dryer output volumes to estimate recovery in plywood panels.

METHODS

Volume recoveries and losses were measured or determined mathematically for the plywood production operations between the dryer and the press. These included the jointing-edge-gluing, reclipping, glue spreading-panel layup, and panel trimming.

The dry veneer samples to be measured at each production operation were randomly selected from veneer loads stacked at the dryers. Sample loads were selected over a 2- to 3-day period. The steps in calculating the loss factors are as follows:

Jointing-edge gluing.--Jointing is the operation necessary to prepare the edges of random width veneer strips for gluing and joining into half- or full-width sheets of veneer. The volume lost in jointing random width veneer was determined by a number of input and output tallies. Each piece of veneer in the loads of random width veneer sampled for jointer loss was measured to determine the total load width in inches. The number of pieces per load was multiplied by the kerf width (about 3/8 inch) of veneer removed by the jointer cutting head. This calculation multiplied by the total number of sample loads measured gave the inches of veneer loss due to jointed kerf. Miscellaneous losses, including breakage or mismanufacture at the jointer and veneer strips not edge-glued because they required additional clipping, were also tallied by inches of width ahead of the edge-gluing equipment.

Edge-glued full sheets that were suitable for plywood manufacture were counted at the outfeed end of the edge-gluer. The number of full sheets was multiplied by the average width per sheet.

The components of the total input to the jointing-edge-gluing operation are the sum in inches of the following: kerf loss, breakage and mismanufacture loss, pieces to be reclipped, and full sheets.

The total output from this operation is the width of the full sheets plus the width of edge-glued pieces that were less than full sheets and were to be returned to reclip. A ratio of this output to the input gave a recovery factor of 0.92527 to reflect the recovery of veneer volume at the jointer-edge-gluer (table 1).

Return for reclipping.--A total of 14.31 percent of the veneer processed through the jointing operation was returned to the reclipping

Table 1.--*Weighted average loss factors and recovery factors for dry veneer, by mill and by production operation*

Production operation	Mill A		Mill B		Mill C		Weighted average
	Factor	*Standard error*	*Factor*	*Standard error*	*Factor*	*Standard error*	
Edge-jointing and gluing:							
Loss	0.068	--	0.086	--	--	--	0.07473
Recovery	.932	±0.0158	.914	±0.0091	(1/)	--	.92527
Not returned to reclip	.841		.880				.85690
Return to reclip	.159	±.0221	.120	±.0146	(1/)	--	[2] .14310
Reclipping:							
Loss	.230	--	.268	--	--	--	.24565
Recovery	.770	±.0104	.732	±.009	(1/)	--	.75435
Trimming:							
Loss	--	--	--	--	--	--	.12059
Recovery	--	--	--	--	--	--	.87941
Patch stock:							
Loss	--	--	--	--	--	--	1.00000
Glue spreading:							
Loss	.086	--	.081	--	0.126	--	.09549
Recovery	.914	±.0084	.919	±.0052	.874	±0.0125	.90451

[1] Data not available.

[2] This is not a loss factor but indicates the percentage of jointed veneer that must be returned to the reclipping operation.

operation. This percentage expressed as a factor, 0.14310, represents the volume of edge-jointed veneer not suitable for production use until it is reclipped (table 1). It alone, of the factors developed in the study, does not represent actual volume loss. It was calculated as a ratio of the inches of veneer needing reclipping to the total jointer-edge-gluer input as defined above. The reclipping loss factor would be applied to the volume that was returned to reclip from jointing.

Reclipping.--Reclipping losses were determined only for edge-glued random width pieces. The random width input to the reclipping operation and the usable veneer output were tallied. A loss factor of 0.24565 was calculated as a ratio of the output-input tallies (table 1).

Relatively few full or half sheets required reclipping after drying. A separate factor was not developed for this loss.

Glue spreading-panel layup.--Volume loss at the glue spreader was determined by the ratio of output volume to input volume. The output volume was made by a count of the untrimmed glue-spread layers of panel size. This count was converted into total inches of width. Veneer losses in terms of overhang (veneer layers in the panel extending beyond a maximum untrimmed panel size) and discards (veneer too thin or too rough to be used) were also tallied in inches of width. Components of the input volume to the glue spreader were the sum of the output, overhang, and discard volumes. The ratio of output to input resulted in a loss factor of 0.09549 which reflects veneer loss at the glue spreader (table 1).

Panel trimming.--Untrimmed plywood panel width was approximately 52 by 100 inches, but it varied with each mill. An average factor for trimming was calculated for each study by multiplying trimmed panel length by width and then dividing by the dimensions of the average untrimmed panel size for each mill. All individual mill factors were combined to obtain an average trimming loss factor of 0.12059 (table 1).

Patch stock production.--Patch stock is strips of veneer 3 to 4 inches wide from which plugs and patches are cut to use in upgrading sheets of veneer and in repairing plywood panels. Experience at plants peeling Douglas-fir has indicated that much of the patch stock comes from half sheets of A grade veneer. The entire production of this veneer grade and size is commonly used for patch stock. Therefore, half sheets of A veneer were included as patch stock input volume but considered to be consumed for patch stock, yielding no output volume. All half sheets of A grade veneer are included in the patch stock loss factor of 1.00000 (table 1).

DISCUSSION

The volume loss factors (and compliment recovery factors) developed from the above procedures for each mill in the study, and the weighted averages are shown in table 1. The weighted factors are the ones to apply.

Although the factors were developed at the major points of veneer loss, it is evident that not all veneer grade items suffer each loss. For instance, random width, 50-inch core stock veneer is not jointed so does not incur any jointer kerf loss. Therefore, veneer grade items would be grouped according to the manufacturing procedures they would undergo and the appropriate factors applied to each group.

General practice in the plywood industry is to edge-joint and glue 102-inch random width veneer. Most of this is in grades A through C.[1] The volume of random width grade D veneer that is edge-glued is unknown but small; nearly all of this material is cut in half for 51-inch-long plywood core stock. Accordingly, volumes of 102-inch random width material expected to be edge-jointed were summed for all studies. This total volume was reduced by the jointing factor (0.07473) which represented kerf and discard loss.

The two no-loss factors were then applied to this reduced volume. These were expressions of the proportions of jointed veneer that must be returned for reclipping (0.14310) and that which is ready for panel layup (0.85690). The volume of veneer (85.69 percent) that went directly to panel layup was then further reduced by a factor to account for panel trimming loss (0.12059). The veneer that was returned to the reclip operation was reduced by a factor (0.24565) which represented the veneer loss from the total reclip input. The reclip output was again reduced by the jointing factor since it would be sent back to the edge-gluer. It was assumed that none of this veneer would again return to the reclip.

The full-sheet output volume from the edge-gluer is ready for panel layup. This volume, reduced by the trimming factor (0.12059), accounts for the loss in trimming veneer sheets to panel size. The sum of the volumes after trimming is the total output volume. An example of the procedure is shown below and illustrated by figure 1. It is based on the recovery factors applied to 200,000 square feet of random width, 102-inch veneer, 3/8-inch basis.

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[1] National Bureau of Standards, U.S. Department of Commerce. U.S. Product Standard PS 1-66. Product Standards Section. 1966.

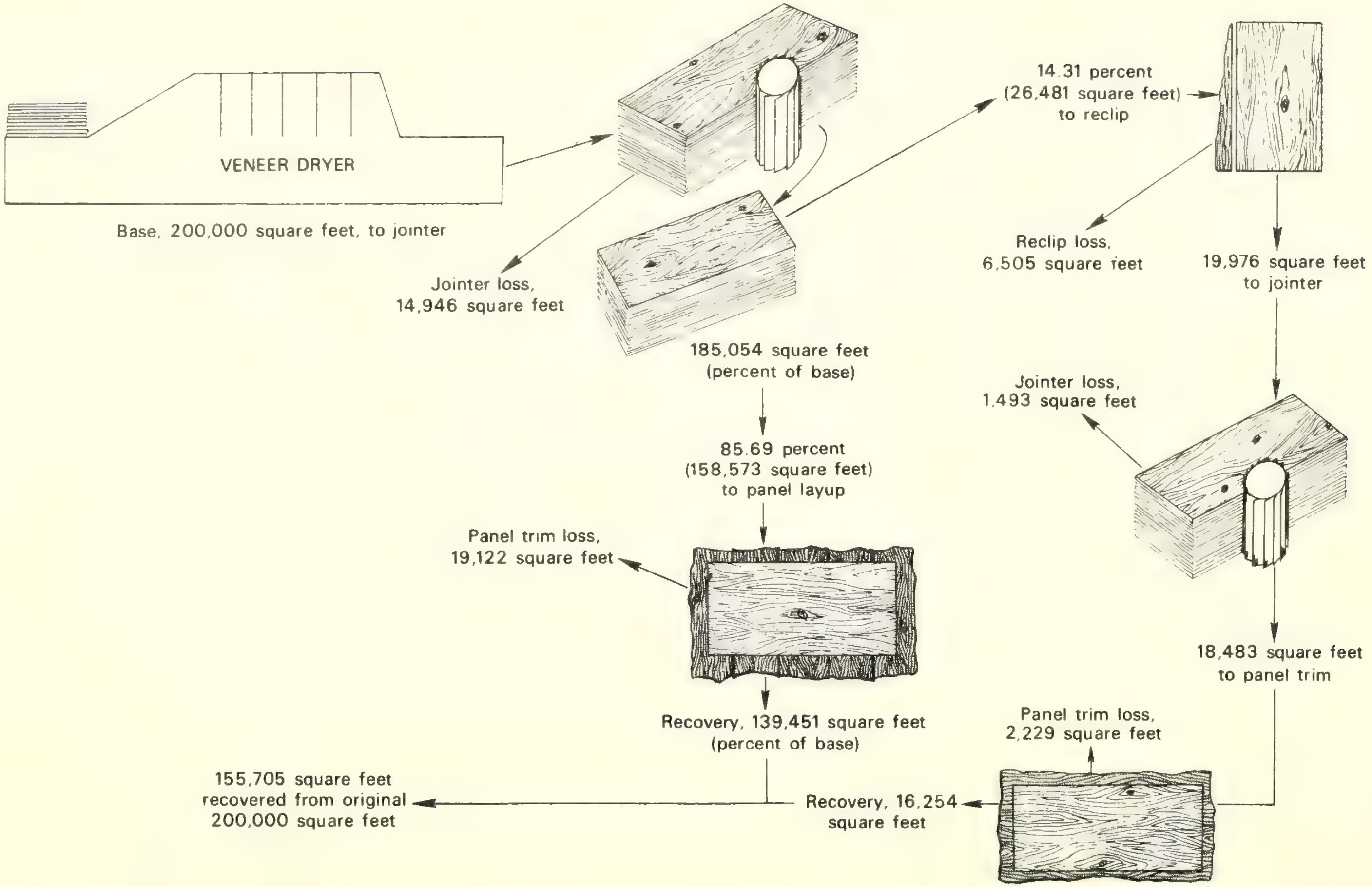
VENEER DRYER
Base, 200,000 square feet, to jointer
Jointer loss, 14,946 square feet
185,054 square feet (percent of base)
14.31 percent (26,481 square feet) to reclip
Reclip loss, 6,505 square feet
19,976 square feet to jointer
Jointer loss, 1,493 square feet
18,483 square feet to panel trim
85.69 percent (158,573 square feet) to panel layup
Panel trim loss, 19,122 square feet
Recovery, 139,451 square feet (percent of base)
Panel trim loss, 2,229 square feet
Recovery, 16,254 square feet
155,705 square feet recovered from original 200,000 square feet

Figure 1.--*Illustration of volume loss from grades A, B, and C, 102-inch random width veneer. (Volumes are in square feet, 3/8-inch basis.)*

Step	Veneer volume	
	Recovery	Loss
	Square feet, 3/8-inch basis	
1. Base: Random width, 102-inch veneer, grades A to C	200,000	
2. Jointing factor, 0.92527 x 200,000 square feet	185,054	14,946
3. Veneer from jointer ready for panel layup, 0.85690 x 185,054 square feet	158,573	
4. Panel trimming factor, 0.87941 x 158,573 square feet	139,451	19,122
5. Veneer from jointer returned to reclip, 0.14310 x 185,054 square feet	26,481	
6. Reclipping factor, 0.75435 x 26,481 square feet	19,976	6,505
7. Jointing factor, 0.92527 x 19,976 square feet	18,483	1,493
8. Panel trimming factor, 0.87941 x 18,483 square feet	16,254	2,229
Recovery (sum of steps 4 and 8)	155,705	
Loss (sum of steps 2, 4, 6, 7, and 8)		44,295

The general plywood industry practice is to edge-joint, glue, or tape half sheets of grade A patch to grade D into full sheets and use them for layup. Rather than develop factors for two loss items, jointer kerf and panel trim, the total loss was computed the same as for full sheets. That is, no kerf loss was applied, but the trimming loss was calculated on the basis of two unjointed half sheets. Volumes of all the half sheets, grades A patch through D, were then totaled, and this volume was reduced by the trimming factor only. This is shown in the example below:

A patch through D, half sheets; volume in square feet, 3/8-inch basis	Loss factor for panel trimming	Final volume
100,000 →	0.12059	87,941

The A grade half sheets used for patch stock are shown in the example below:

A, half sheets; volume in square feet, 3/8-inch basis	Loss factor for patch stock	Final volume
4,000	1.00000	0

As previously stated, it was assumed that all 102-inch random width D grade would be used as plywood core stock. This volume plus the volume of all grades of 50-inch random width veneer was reduced by the loss factor for glue spreading. The resultant volume was again reduced by application of the trimming factor. Thus the final volume of all core stock reflected both spreading and trimming losses. This procedure is illustrated in figure 2.

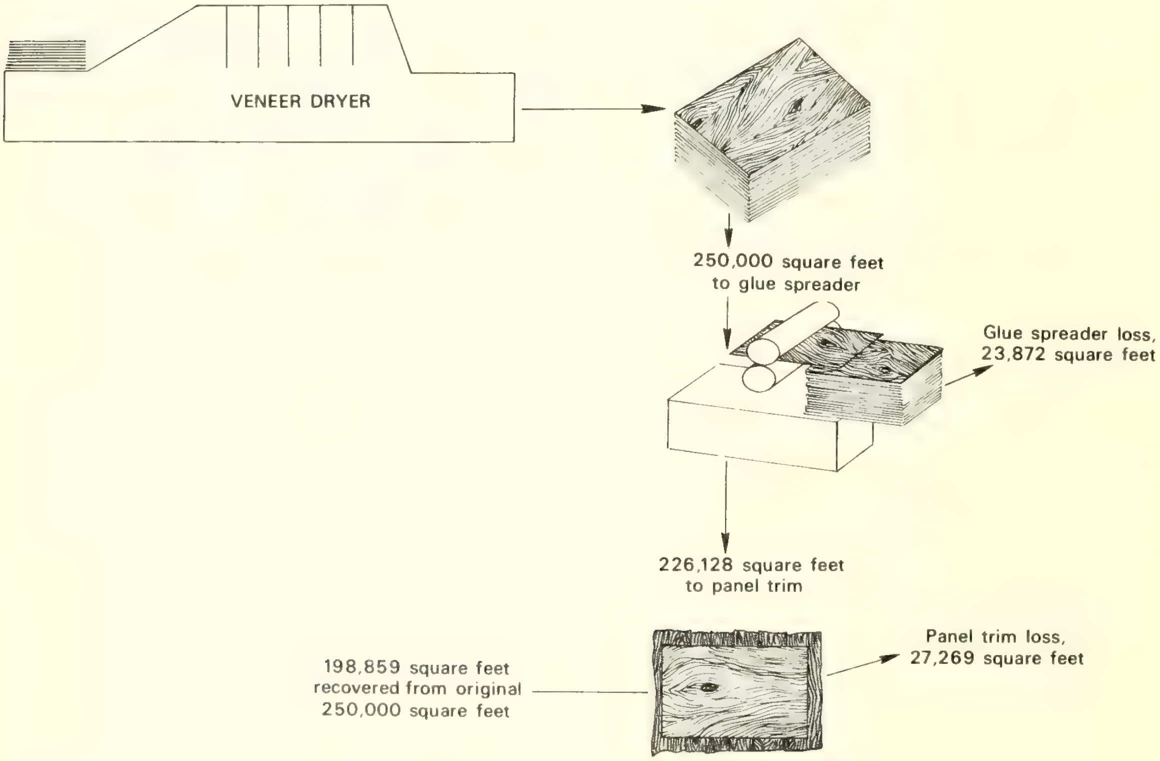
VENEER DRYER
250,000 square feet to glue spreader
Glue spreader loss, 23,872 square feet
226,128 square feet to panel trim
Panel trim loss, 27,269 square feet
198,859 square feet recovered from original 250,000 square feet

Figure 2.--*Illustration of volume loss factors for all grades 50-inch random width veneer and grade D 102-inch random width veneer. (Volumes are in square feet, 3/8-inch basis.)*

Full sheets of veneer are used in the condition and size they are when stacked out of the veneer dryer or at the patching equipment. The only production loss for full sheets occurs when the laid-up panel is trimmed to finished panel size. Damage-type losses from poor handling procedures in the plant were not measured. Therefore, the volumes of full sheets from all studies were summed and reduced by just the trimming loss factor. This calculation is the same as was applied to the half sheets and is shown in the example below:

All grades, full sheets; volume in square feet, 3/8-inch basis	Loss factor for trimming	Final volume
500,000 →	0.12059	439,705

A single overall factor is determined by a ratio of the final output volumes of all veneer by grade and size as determined by the factors and the original input volumes. This gives a loss factor of 16.3 percent from the total volume of dry, untrimmed veneer tallied at the dry chain to the plywood panel volume at the shipping point.

Veneer item	Veneer input volumes from examples	Veneer output volumes as determined by loss or recovery factors
	- - Square feet, 3/8-inch basis - -	
Random width, 102 inches, grades A to C	200,000	155,705
Half sheets, grades A patch to D	100,000	87,941
Half sheets, grade A	4,000	0
Random width, 50 inches, all grades; 102 inches, grade D	250,000	198,859
Full sheets, all grades	500,000	439,705
	1,054,000	882,210

$$\frac{882,210}{1,054,000} = 0.837 \qquad 1.000 - 0.837 = 0.163 \text{ loss factor}$$

Plywood panel sanding loss was not measured during these tests.

CONCLUSIONS

Losses of rough dry veneer between the dry chain and the trimmed plywood panel were determined from a series of detailed studies. Total losses from all sources were found to be approximately 16 percent of the original volume measured at the dry chain. This figure has since been confirmed by one large veneer mill peeling coast Douglas-fir through test procedures similar to these.

The individual volume loss factors will provide an individual veneer mill with factors to estimate output volumes from veneer dryer production volumes. Any mill interested in learning the extent of its losses at the various processing points in comparison with these factors can conduct similar tests and compare their results with those shown here. The factors could also be useful where information on current veneer losses is needed to properly evaluate new processes or equipment.

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. Forest Service RESEARCH NOTE

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PNW-135 *November 1970*

EFFECT OF DATE OF GRAFTING ON SURVIVAL IN DOUGLAS-FIR

by

Donald L. Copes, *Plant Geneticist*

ABSTRACT

A field study of 1,300 grafts in western Oregon indicated that 90-percent or higher survival was obtained when Douglas-fir was grafted from early spring to mid-May. Fall grafting in September and October was especially unfavorable.

INTRODUCTION

Orchardists find it necessary to make hundreds of grafts each year to establish and maintain Douglas-fir seed orchards. It is usually most economical to complete grafting an orchard in as few years as possible. Each year the propagators try to anticipate when or if grafting success is likely to be too low to justify production costs. Results of the following study should help seed orchard managers select the correct termination date of grafting. Survival of grafts made each month from April to October is documented.

METHODS

Field grafting was done in 1968 and 1969 near Corvallis, Oregon. One hundred top-cleft grafts were made each year during the first week of every month, April through September in 1968, and April through October in 1969. Each month, scions from four clones were top-cleft-grafted on twenty-five 9- to 12-year-old rootstocks. Scions from the same four clones were grafted both years. One experienced grafter did all the grafting, using uniform techniques throughout the study. No polyethylene bags or protective coverings were placed over the scions after grafting. Survival was recorded in June following the year of grafting.

Scions for grafting in 1968 were collected on March 28, divided into six groups, and stored at 35° F. until time of grafting. Scions for grafting in 1969 were collected on March 28 and August 4 and 24. The March 1969 collection was handled as the 1968 collection, except that only enough scions were stored for 4 months' grafting. Scions for 3 additional months were collected in August. Scions collected on August 4 were grafted the same day, and scions collected on August 24 were divided into two lots and stored at 35° F. until grafted in September and October.

RESULTS AND DISCUSSION

Propagators in the Pacific Northwest usually begin grafting in March. Survival of March grafts is normally 90 percent or higher. Results of the present study (table 1) indicate that 90-percent or higher graft survival can be expected until mid-May. Thus, in western Oregon there is a 2½-month interval, March to mid-May, when 90-percent or higher graft survival can be obtained by an experienced grafter. Grafting after that time resulted, with exception of July 1969, in progressively lower survival.

Table 1.--*Graft survival, maximum temperature, precipitation, and evaporation during the month of grafting*[1]

Month of grafting	Graft survival		Average maximum temperature		Total monthly precipitation		Total monthly evaporation	
	1968	1969	1968	1969	1968	1969	1968	1969
	--*Percent*[2]--		---*Degrees F.*---		------------*Inches*------------			
April	97	97	58.9	58.8	1.50	1.94	2.99	3.24
May	94	96	64.8	70.1	3.45	1.64	4.22	6.05
June	80	67	72.8	74.5	.79	2.46	6.20	6.31
July	52	7	81.4	78.9	.34	.05	8.43	7.62
August	35	19	76.2	79.0	5.24	0	6.17	8.51
September	23	13	72.7	74.8	1.99	3.62	4.40	5.34
October	--	4	--	60.4	--	3.91	--	2.16

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[1] Weather data taken from the Corvallis State College Station. U.S. Dep. Commerce, Climatological data, Oregon, vols. 74 and 75.

[2] Survival was recorded in June following the year of grafting.

Long-term storage had no apparent influence on initial graft survival, but one undesirable consequence was discovered. The vernalization requirements had already been satisfied so vegetative buds of scions collected and stored in March 1968 flushed 30 to 40 days after grafting. Thus, scions grafted in August and September flushed buds in September to October or October to November, respectively. These late growth flushes produced succulent shoots which were not adequately hardened off to protect them from severe frost damage. In order to overcome the frost problem in 1969, scions for grafting in August, September, and October were collected in August from the 1969 new growth. Buds from these unchilled scions did not flush until the following spring--thus no frost damage was visible. Time of scion collection is not considered the cause of lower graft survival in August and September 1969 than in the same months in 1968 because lower survival from June and July 1969 grafts indicated a poorer summer for grafting.

This study was designed to discover what percent of graft survival could be obtained by grafting at 1-month intervals and not specifically to explore causes of reduced survival. But it is logical to compare survival results with weather data in order to find leads which might be useful in extending the grafting season or in determining the favorable grafting period for areas with slightly dissimilar climates. Weather records were checked to determine the relationship between graft survival and precipitation, maximum temperature, and evaporation. An inverse correlation between graft survival and average maximum temperature and total evaporation was found. High graft survival (94 to 97 percent) was obtained during the cool months of April and May (table 1). Grafts made in June showed reduced survival (67 to 80 percent), and even lower survival resulted when grafting was done during the hot, dry days of July and August (7 to 52 percent).

It should be noted that moderately successful summer grafting (58 to 70 percent survival) was achieved in other studies when protective bags were placed over the grafts.[1] Unfortunately, this type of grafting is slow and thus results in high production costs; therefore, the method is not used for normal orchard establishment.

A third factor, length of favorable growing season after grafting, was evident in grafts made in September and October. Grafts made during those 2 months had lower average survival than that obtained in other months (4 to 23 percent). This was somewhat unexpected because temperature and precipitation were much more favorable than in July and August. The hypothesis is that union formation in September and October grafts was not completed before growth ceased and that the scions were more subject to winter injury than were grafts made earlier in the growing season. This was especially noticeable in October grafts, of which only 4 percent survived.

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[1] Personal communication from Joe Wheat, Industrial Forestry Association, Olympia, Wash.

A survey of six seed orchardists from Oregon, Washington, and British Columbia revealed that five in Oregon and Washington had poor results with fall grafting. The one positive report came from British Columbia, where an average of about 80 percent of the fall grafts survived.[2]

All environmental factors which lead to water stress conditions in the scion and rootstock probably have a combined effect which is detrimental to graft survival. Lack of precise fit of graft survival with temperature, precipitation, or evaporation data suggests that no single weather factor can be used to explain all survival variation. This was evident in the precipitation and the daily maximum temperature data; high temperatures and low precipitation in July 1968 and 1969 did not result in comparably low survival (52 vs. 7 percent) (table 1). This difference between years is significant at the 99-percent level.

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[2] Personal communication from Chris Heaman, Research Division, British Columbia Forest Service, Victoria, B.C.

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PRELIMINARY STUDY OF DYNAMIC CHARACTERISTICS OF SKYLINE LOGGING

by

Ward W. Carson, *Research Mechanical Engineer*

ABSTRACT

Skyline logging systems are used extensively for harvesting timber in rough terrain. Their design and operation depend upon a knowledge of static and dynamic characteristics of the system. This note discusses the results of a preliminary study of the dynamic characteristics of skyline logging.

1.0 INTRODUCTION

Skyline logging systems, used extensively for harvesting timber in rough terrain where a dense road system is undesirable, involve cables or wire ropes suitably anchored and tensioned. A concentrated log load is supported in the span between the anchor points and transported to another point in the span, called a landing. A yarder, located at one anchor point in the cable system, provides the powered drums used to manipulate the cables in the log yarding process.

The logging industry has used skylines for years. Although the design details of these systems were greatly ignored in the past, emphasis on operational efficiency and more sophisticated yarder designs have generated a requirement for more technical knowledge of these cable systems. Broken skylines and anchor failures are becoming common--17 known cases were recorded in the 1969 operating season alone. One such failure resulted in a quarter of a million dollars of timber being burned. Most of these failures are directly attributable to a lack of appreciation for the statics and dynamics of skyline design.

The logging industry needs better design tools with which to treat the layout of skyline systems and the design of the equipment to be used in these systems. Information on the dynamic characteristics of these systems required to implement these tools is not available.

This research note describes the problems related to a study of skyline logging dynamics. Previous work in the field is summarized, and the results of preliminary studies are reported.

1.1 Skyline Configurations

Several configurations of skylines are employed by the logging industry. Those most common, shown in figures 1, 2, and 3, are considered here.

1.1.1 Standing skyline (fig. 1)

This configuration consists of a fixed length of suspended cable (the skyline) anchored at a tailhold (usually a stump) and a headspar (usually a metal tower attached to the yarder). The log load is attached to a carriage, designed to roll freely on the skyline. The carriage and log are drawn along the skyline with another cable, the main line, which is powered by a drum on the yarder.

1.1.2 Live skyline (fig. 2)

This configuration is identical to the standing skyline except that the skyline length can be adjusted at the yarder during the process of picking up and yarding the log. While the skyline is anchored at the tailhold, the length is adjusted at the yarder end by a powered drum. The main line and carriage operate as in the standing skyline configuration.

1.1.3 Running skyline (fig. 3)

This configuration is similar to the live skyline except that the skyline, in this case called a haulback, continues through a block at the tailhold and terminates at the carriage. This feature allows the system to operate on any slope, whereas the standing and live skyline systems depend upon gravity location of the carriage. Again, the main line operates as in the other configurations.

1.2 Loading

The ratio of live load to dead load in a logging skyline clearly distinguishes it from other suspension structures such as bridges and roofs. The nature of the rough terrain where skylines are commonly operated presents several interesting loading situations. The forcing functions defined here represent typical loading situations expected to generate critical cable tensions or operational problems for the yarding equipment.

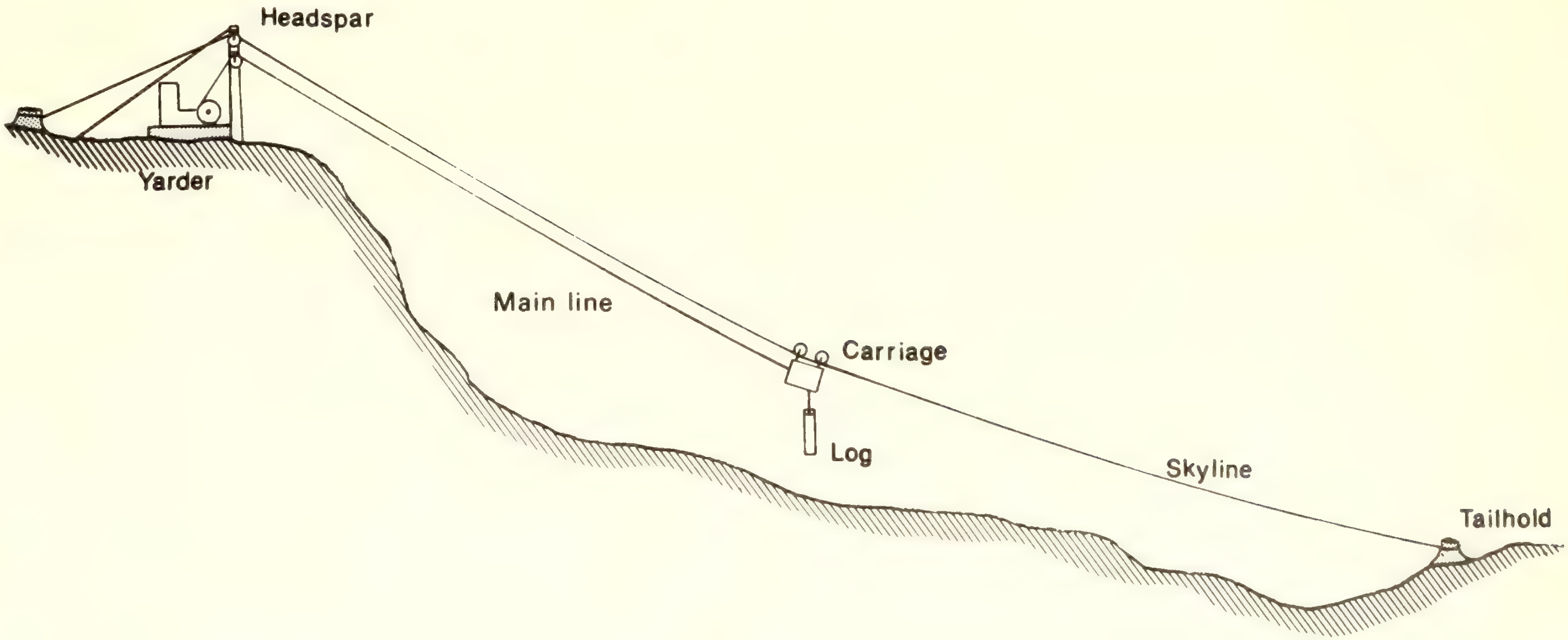


Figure 1.—Standing skyline, gravity carriage.

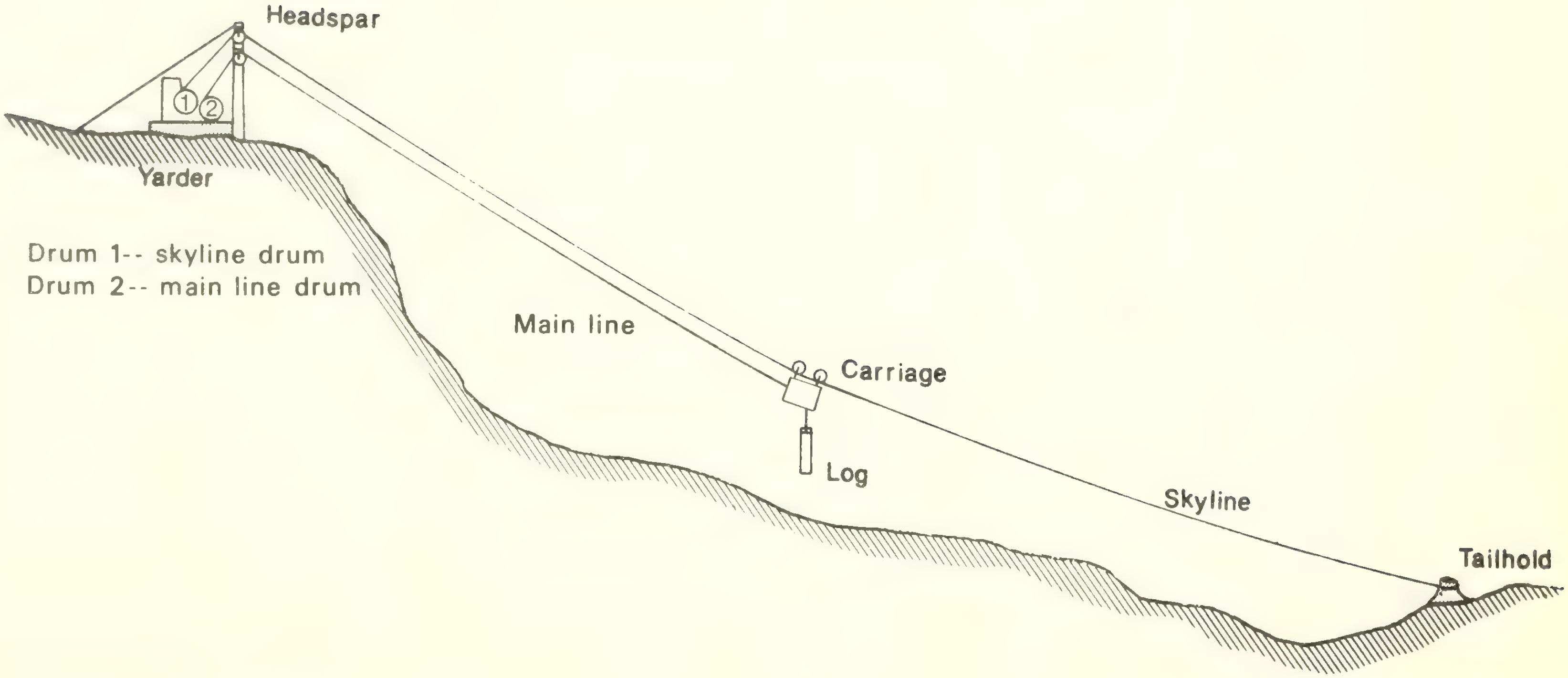


Figure 2.—Live (slackline) skyline, gravity carriage. Skyline drum powered so skyline length is varied during yarding operation.

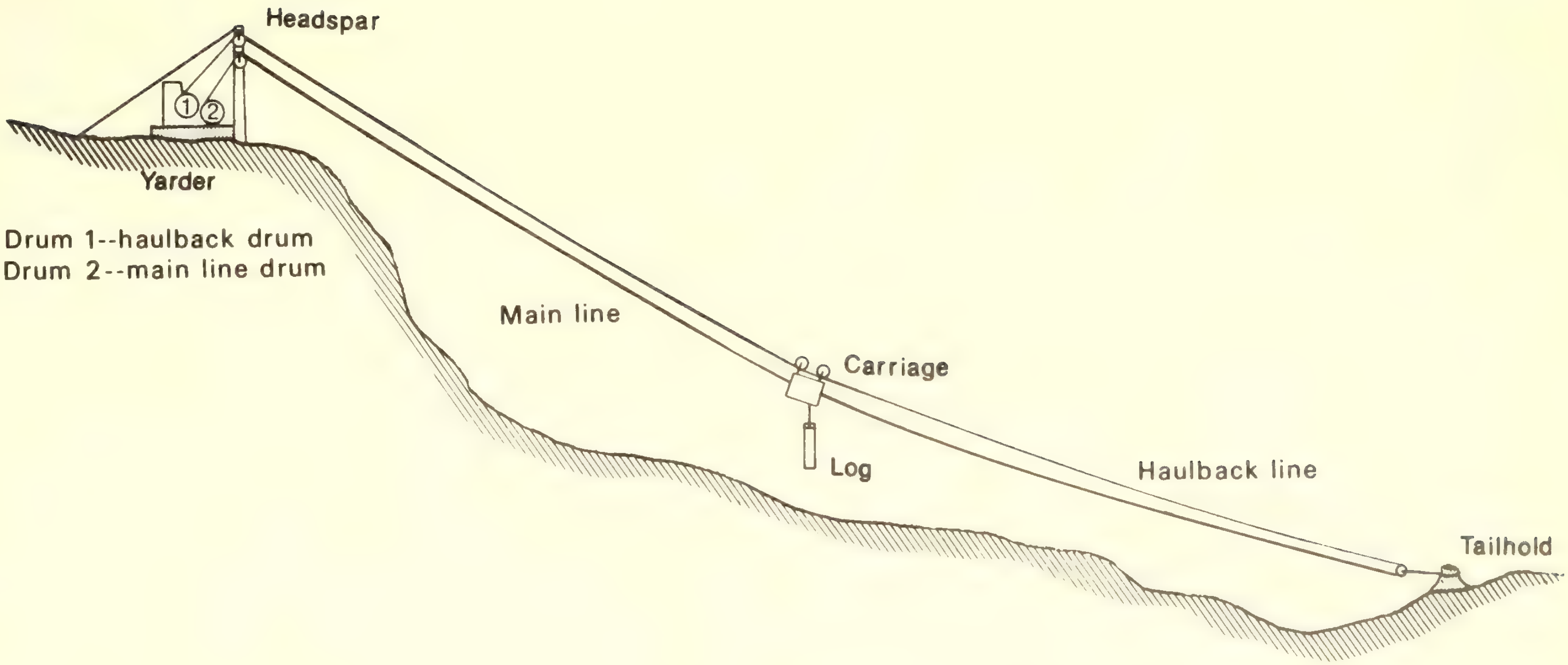
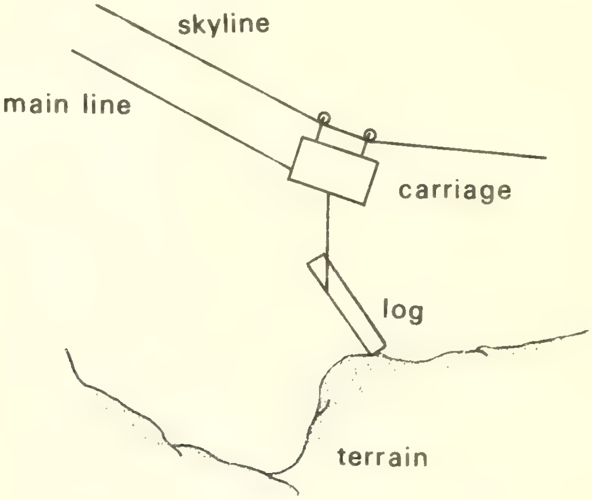


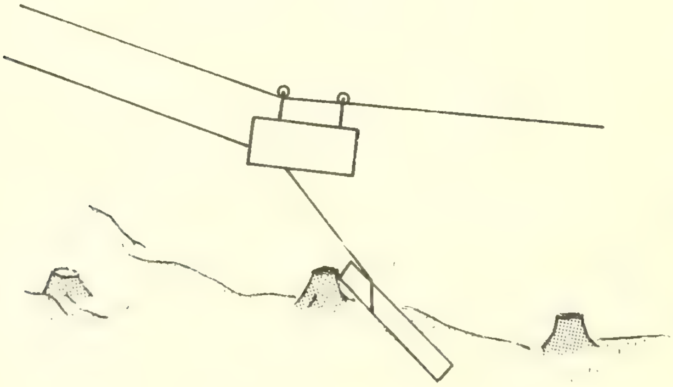
Figure 3.—Running skyline. Drums 1 and 2 on the yarder are interlocked for horsepower exchange during yarding operation.

During yarding, a log load will at times go from being partially supported by the ground to being freely suspended, as when the log falls off a high point in the terrain.



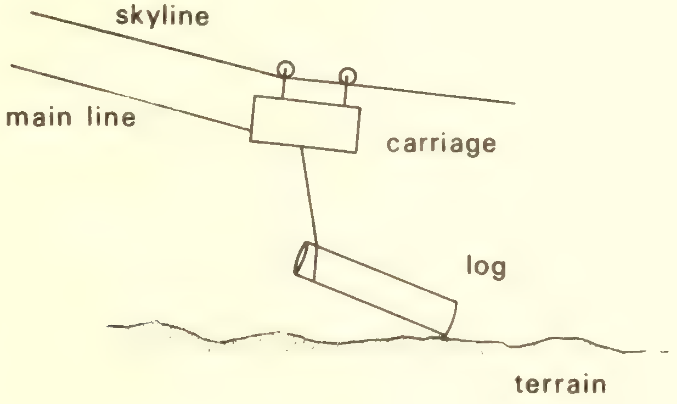
Suddenly applied concentrated mass.

A log being dragged at some velocity will commonly get "hung up" by some obstacle in the terrain.



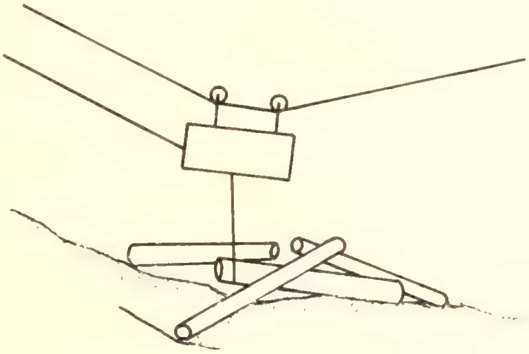
Stoppage of horizontal travel.

Frictional forces developed at the ground during normal yarding cause heavy logs to move in an oscillatory motion.



Normal dragging of heavy log.

When the load is "hung up," the yarder operator will usually tension all lines in an attempt to free the load. If the load comes free, the vibration of the cable is not expected to generate dangerous tensions; however, the input to the yarder and its response should prove interesting.



Log "hung up" under other logs.

2.0 BACKGROUND

Before the problem was analyzed, the literature of related work was reviewed and is summarized in this section.

2.1 Static

The mathematical formulation of the static skyline problem is treated under the more general classification of catenary problems *(8)*. Specific treatment of logging skylines supporting concentrated loads appeared in a paper by Anderson *(2)* and in a later work by Mills *(10)*. These papers establish the mathematical formulation of the problem and give closed-form expressions for the skyline variables.

The catenary description of the static skyline problem consists of a set of nonlinear, transcendental equations. The number of equations is directly related to the number of cable segments in the configuration. Although solution of these equations presents a difficult numerical problem, the problem has been treated extensively by several investigators *(5, 12, 13)*.

2.2 Dynamic

The transverse vibration of a heavy, taut string is a classic problem in wave motion. With assumptions of small variations in tension and small deflections, the string's behavior is described by the familiar wave equation,

$$\frac{\partial^2 y}{\partial x^2} = \frac{\rho}{T}\frac{\partial^2 y}{\partial t^2}\ .$$

Many problems described by this equation have been solved *(7)*.

The first extensive analysis of the nonlinear problem was done by Carrier *(3, 4)*. Carrier applied first the perturbation method *(3)* and later a method using an analogy with the boundary layer problem *(4)*. Both methods were approximations for the range of moderately large amplitude vibrations and were primarily concerned with the propagation of localized deformations.

The oscillatory failure of the Tacoma Narrows bridge *(1)* stimulated considerable interest in cable vibrations in response to aerodynamically generated oscillatory loadings. The primary concern of this analytical work *(15, 16, 17, 21)* was to predict the structure's natural frequencies of vibration. Considerable experimental work was done with models to develop and substantiate semiempirical expressions for natural frequencies as a function of span, deflection, mass, etc. The philosophy was to develop extremely conservative designs in terms of keeping the natural frequencies away from the aerodynamic eddy frequency as predicted by the Von Karman vortex theory.

The response of an elastic, uniform, flexible cable to a suddenly imposed velocity at some point of its length has been examined by a number of investigators *(6, 11, 18)*. These studies were promoted primarily by an interest in design of arresting cables for aircraft on naval aircraft carriers. Ringleb *(18)* presented a particularly interesting analysis of the motion and stress of an initially straight elastic cable subjected to impact. He was able to develop closed-form solutions for stress, transverse and longitudinal motion, and energy in cables subjected to impact loads. Although the limited geometry of Ringleb's problem does not make it directly applicable to the skyline logging problem, it should be of valuable assistance.

Some work has been done on the cable dynamics associated with towing submerged bodies, such as sonar vehicles or oceanographic instrument packages *(20)*. This work was restricted to one-dimensional geometry with the boundary conditions of a large mass on the opposite end of a tether experiencing large amplitude, sinusoidal oscillations.

The most recent work in cable dynamics has been stimulated by an interest in suspended roof structures. Architects have promoted the use of these structures where long spans are required *(9, 14, 24)*. Although the literature for static design is fairly complete *(12, 19)*, the dynamics have received very little treatment. Individual designs have been modeled and tested for response to wind and seismic loading *(22, 23)*, but little has been done in the way of general theory. Mollmann ([illegible]) has analyzed the single cable for both static and dynamic characteristics; however, small vibrations are assumed in the dynamic treatment.

No work, apparently, has been done on the dynamics of logging cable systems. Some experimental data have been collected by this Station; however, the difficulty and expense of measuring and controlling parameters have prohibited completion of most of these tests.

3.0 PROBLEM FORMULATION

Cables, when treated as a subject in mechanics, are often assumed to be inextensible and completely flexible. Assumptions of small deflections and approximately constant tensions also are conveniently applied to maintain the linearity of the problem. In the present formulation, only the assumption of complete flexibility will be retained. The equations developed are highly nonlinear and a finite difference approach to solution is discussed.

3.1 Problem Geometry

The two-dimensional geometry of three specific states of a cable are of interest in this problem: the unstrained state, the initial state, and the final state.

The unstrained state is the natural condition of the cable when the cable force is zero. The geometry of this state is not of interest; however, it serves as a convenient reference in the stress-strain and strain-displacement expressions, and its relationship to the other states will be important.

The initial state is the static equilibrium configuration of the cable due to a given load. The position vector (fig. 4) describing this state in Cartesian coordinates is taken as:

$$\vec{r}(s) = x(s)\vec{i} + y(s)\vec{j} \ ,$$

where s is the arc length in this state and is taken as a parameter, x, y are Cartesian coordinates of figure 4, and $\vec{i}, \vec{j}$ are the unit vectors of the coordinate system.

The final state of the cable is the configuration existing at anytime t. Its position vector is related to the initial state through

$$\vec{R}(s) = \vec{r}(s) + \vec{u}(s) \ ,$$

where $\vec{u}(s)$ is called the displacement vector and has Cartesian components.

$$\vec{u}(s) = v(s)\vec{i} + w(s)\vec{j}$$

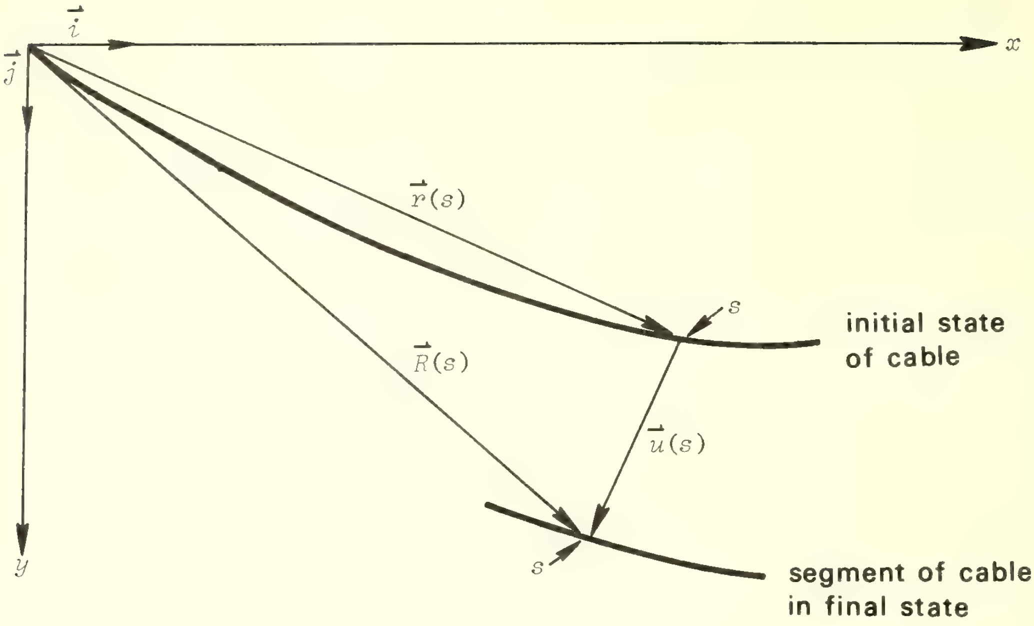


Figure 4.—Problem geometry.

The unit tangent vectors at any point in both the initial and final positions are required. These are expressed as

$$\vec{t}_{\text{initial}} = \frac{\dfrac{\partial x}{\partial s}\vec{i} + \dfrac{\partial y}{\partial s}\vec{j}}{\sqrt{\left(\dfrac{\partial x}{\partial s}\right)^2 + \left(\dfrac{\partial y}{\partial s}\right)^2}}$$

and

$$\vec{t}_{\text{final}} = \frac{\left(\dfrac{\partial x}{\partial s} + \dfrac{\partial v}{\partial s}\right)\vec{i} + \left(\dfrac{\partial y}{\partial s} + \dfrac{\partial w}{\partial s}\right)\vec{j}}{\sqrt{\left(\dfrac{\partial x}{\partial s} + \dfrac{\partial v}{\partial s}\right)^2 + \left(\dfrac{\partial y}{\partial s} + \dfrac{\partial w}{\partial s}\right)^2}} \quad .$$

3.2 Stress-Strain Relationship

A linear stress-strain relationship is assumed which is referenced to the arc length of the cable in the unstrained state, namely,

$$T = EA\,\frac{dS - ds_o}{ds_o}$$

or

$$T = EA\,\gamma_o \quad ,$$

where

T = the tension,

E = Young's modulus for the cable,

A = the reference cross-sectional area of the cable,

dS = the cable element arc length in some final state,

ds_o = the cable element arc length in the unstrained state,

and, as indicated,

$$\gamma_o = \frac{dS - ds_o}{ds_o} .$$

This stress-strain relationship assumes that the cross-sectional dimension of the cable, small compared to its length, changes negligibly with tension.

Tension is the only force considered at a cable cross section. Bending resistance is considered negligible.

3.3 Strain-Displacement Relationship

The element arc lengths for the initial and final states are expressed in terms of the position vectors. We have for the initial state,

$$dr = \left(\left(\frac{\partial x}{\partial s}\right)^2 + \left(\frac{\partial y}{\partial s}\right)^2\right)^{1/2} ds$$

and for the element arc length in the final state,

$$dR = \left(\left(\frac{\partial x}{\partial s} + \frac{\partial v}{\partial s}\right)^2 + \left(\frac{\partial y}{\partial s} + \frac{\partial w}{\partial s}\right)^2\right)^{1/2} ds .$$

The element arc length in the unstrained state must be derived from the initial state and the stress-strain relationship. The tension in the initial state, F, is determined from a static equilibrium solution. This allows the relationship,

$$F = EA\,\gamma_o\Big|_{\substack{\text{initial}\\ \text{state}}} = EA\left(\frac{\dfrac{dr}{ds} - \dfrac{ds_o}{ds}}{\dfrac{ds_o}{ds}}\right) ,$$

which can be used to express

$$\frac{ds_o}{ds} = \frac{dr}{ds}\Bigg/\left(\frac{F}{EA} + 1\right)$$

From this, the strain-displacement relationship becomes

$$\gamma_o = \frac{\left[\left(\frac{\partial x}{\partial s} + \frac{\partial v}{\partial s}\right)^2 + \left(\frac{\partial y}{\partial s} + \frac{\partial w}{\partial s}\right)^2\right]^{1/2} \left(\frac{F}{EA} + 1\right)}{\left[\left(\frac{\partial x}{\partial s}\right)^2 + \left(\frac{\partial y}{\partial s}\right)^2\right]^{1/2}} - 1 .$$

3.4 Equation of Motion

In the equation of motion, we shall consider the body forces of $\omega_o(s)$, cable weight per foot directed vertically, and $\vec{p}(s)$, any externally applied force per foot of arc length. This force need only be piecewise continuous and will represent the concentrated loads to be considered. Tensions at the cable element cross sections are directed along the cable's tangent. The force balance on this element (fig. 5) can be written down immediately as

$$\frac{\partial(T\vec{t})}{\partial s} + \vec{p} + \omega_o\vec{j} = \frac{\omega_o}{g}\frac{\partial^2\vec{u}}{\partial t^2} .$$

For our solution, this is most conveniently expressed in its horizontal and vertical components as follows for x-direction

$$\frac{\partial}{\partial s}\left[T\frac{\frac{\partial x}{\partial s}+\frac{\partial v}{\partial s}}{\sqrt{\left(\frac{\partial x}{\partial s}+\frac{\partial v}{\partial s}\right)^2+\left(\frac{\partial y}{\partial s}+\frac{\partial w}{\partial s}\right)^2}}\right]+p_x=\frac{\omega_o}{g}\frac{\partial^2 v}{\partial t^2}$$

and y-direction

$$\frac{\partial}{\partial s}\left[T\frac{\frac{\partial y}{\partial s}+\frac{\partial w}{\partial s}}{\sqrt{\left(\frac{\partial y}{\partial s}+\frac{\partial v}{\partial s}\right)^2+\left(\frac{\partial y}{\partial s}+\frac{\partial w}{\partial s}\right)^2}}\right]+p_y+\omega_o=\frac{\omega_o}{g}\frac{\partial^2 w}{\partial t^2} .$$

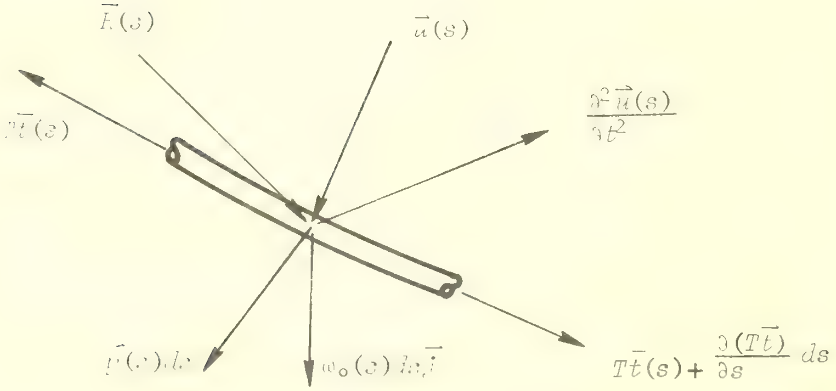

$\vec{R}(s)$
$\vec{u}(s)$
$T\vec{t}(s)$
$\frac{\partial^2\vec{u}(s)}{\partial t^2}$
$\vec{p}(s)ds$
$\omega_o(s)\,ds\,\vec{j}$
$T\vec{t}(s)+\frac{\partial(T\vec{t})}{\partial s}ds$

Figure 5.—Forces on cable element.

3.5 Finite-Difference Solution

To conduct a preliminary investigation of the cable problem, an explicit, finite difference scheme was prepared. Some reference to the modeling of shell dynamics was made in preparing this algorithm.

The node network consists of a series of alternating stress and mass points. The mass is considered concentrated at the mass points, and the tension acts at the stress points. The appropriate parameters are evaluated at each point (fig. 6).

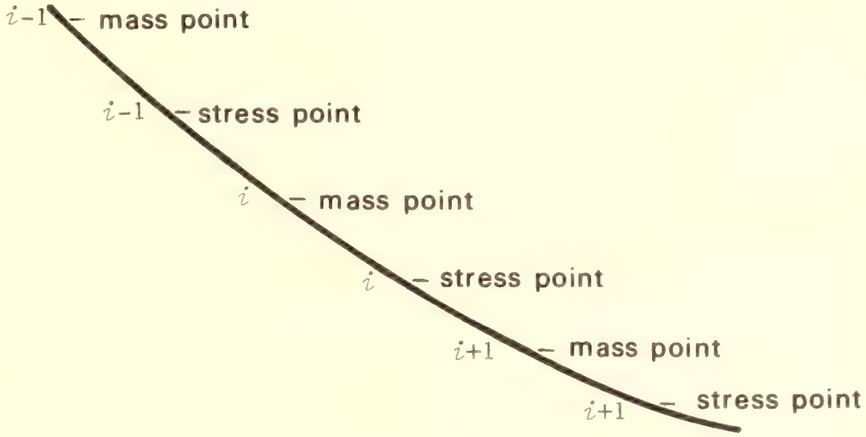


Figure 6.—Node arrangement for finite-difference solution.

Mass points.--The displacements are evaluated at the mass points. Body forces, ω_o and p, masses, and accelerations are also determined at these points.

The finite difference expressions are as follows for accelerations

$$\ddot{v}_i = \frac{\left[\left(p_x\right)_i + \dfrac{T_i \left[\dfrac{\frac{\partial x}{\partial s} + \frac{\partial v}{\partial s}}{q} \right]_i - T_{i-1} \left[\dfrac{\frac{\partial x}{\partial s} + \frac{\partial v}{\partial s}}{q} \right]_{i-1}}{\partial s} \right]}{(\omega_o)_i/g}$$

and

$$\ddot{w}_i = \frac{(\omega_o)_i + \left(p_y\right)_i + \dfrac{T_i \left[\dfrac{\frac{\partial y}{\partial s} + \frac{\partial w}{\partial s}}{q} \right]_i - T_{i-1} \left[\dfrac{\frac{\partial y}{\partial s} + \frac{\partial w}{\partial s}}{q} \right]_{i-1}}{\partial s}}{(\omega_o)_i/g} ,$$

where

$$q_i = \left[\left(\frac{\partial x}{\partial s} + \frac{\partial v}{\partial s}\right)^2 + \left(\frac{\partial y}{\partial s} + \frac{\partial w}{\partial s}\right)^2\right]^{1/2}$$

and where T and the gradients are stress point variables.

The displacements are evaluated from the accelerations with the central difference expression

$$\ddot{d}(t + \Delta t) = \frac{d(t + \Delta t) - 2d(t) + d(t - \Delta t)}{\Delta t^2}$$

or

$$\ddot{d}(t + \Delta t) = \frac{[d(t + \Delta t) - d(t)] - [d(t) - d(t - \Delta t)]}{\Delta t^2} ,$$

which can be expressed as

$$\ddot{d}(t + \Delta t) = \frac{\Delta d(t + \Delta t) - \Delta d(t)}{\Delta t^2} .$$

This gives the following expressions for displacements:

$$v_i(t + \Delta t) = v_i(t) + [\ddot{v}_i(t)\ \Delta t^2 + \Delta v_i(t)]$$

and

$$w_i(t + \Delta t) = w_i(t) + [\ddot{w}_i(t)\ \Delta t^2 + \Delta w_i(t)] .$$

Stress points.--The displacement gradients, tangent vectors, and element strains are computed at the stress points. The tensions influencing the adjacent mass points are also evaluated here.

The stress point variables are completely evaluated from adjacent mass point information. The gradients come directly from the displacements as

$$\left(\frac{\partial x}{\partial s}\right)_i = \frac{x_{i+1} - x_i}{ds} .$$

$$\vdots$$

The strain and tension also follow directly from the mass point information as

$$(\gamma_o)_i = \frac{\sqrt{\left(x_{i+1} - x_i + v_{i+1} - v_i\right)^2 + \left(y_{i+1} - y_i + w_{i+1} - w_i\right)^2}}{\sqrt{\left(x_{i+1} - x_i\right)^2 + \left(y_{i+1} - y_i\right)^2} \Big/ \left(\frac{F_i}{EA} + 1\right)} - 1$$

and

$$T_i = EA(\gamma_\sigma)_i \; .$$

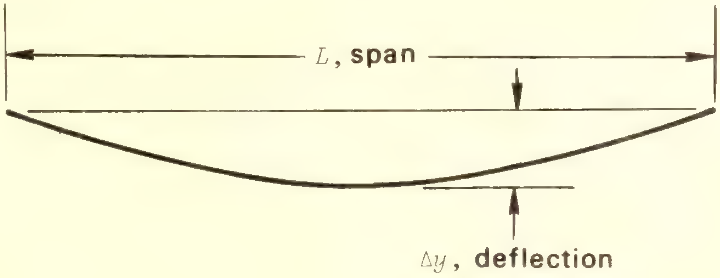
The central difference equations used here assume that the stress points are midway between mass points and mass points are midway between stress points, along the cable arc length. This is not strictly true; however, the variations observed are negligible and can be ignored.

4.0 PRELIMINARY RESULTS

The finite difference solution is applied to two examples to investigate potential problem areas. Two major problems encountered in this preliminary study were limiting compression in the cable and accounting for energy variations during the cable vibrations.

4.1 Examples Studied

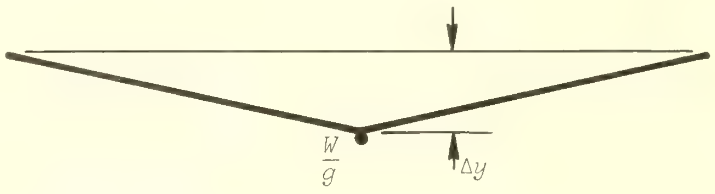
The response to the sudden application of a midspan mass is examined. The static configuration described in figure 7 is the initial state of the two examples studied. This represents a completely flexible cable, pinned at its anchor points and hanging under the load of its own weight, assumed to be uniformly distributed along its length. The catenary expressions are used as the governing equation.



L, span = 1,003.53 feet
Δy, deflection = 100.72 feet
s, line length = 1,030.0 feet
ω , line weight per foot = 3.16 pounds/foot
E, cable modulus = 1.9×10^7 pounds/square inch
A, reference cross section = 0.85 square inch
H, tension at midspan = 4,001.5 pounds

Figure 7.—Initial state of cable in example problems.

The final static state of the two examples is established to serve as reference points in the energy studies. The two configurations, 2,000-pound loading and 5,000-pound loading (both at midspan), as described in figures 8 and 9, represent gradual application of the loads. The final state line lengths are compatible with the linear stress-strain relationship used. The reference displacement, Δy_{ref}, is defined as the deflection the load experiences when gradually applied. The values are given in the figures.



W, weight of load = 2,000.0 pounds

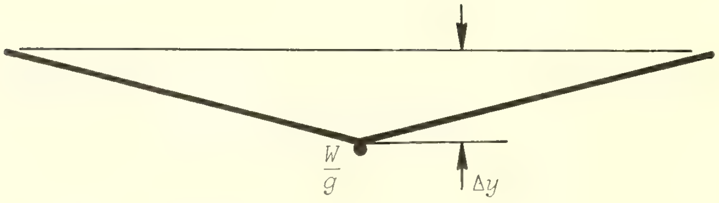
T, tension at anchors = 8,446.98 pounds

Δy, static deflection = 113.01 feet

Δy_{ref}, deflection from initial state = 12.29 feet

s, line length = 1,030.262 feet

Figure 8.—Final static state of 2,000.0-pound load.



W, weight of load = 5,000.0 pounds

T, tension at anchors = 14,860.45 pounds

Δy, static deflection = 116.372 feet

Δy_{ref}, deflection from initial state = 15.652 feet

s, line length = 1,030.67 feet

Figure 9.—Final static state of 5,000.0-pound load.

4.2 Energy Considerations

During the investigation of response, the strain, kinetic, and potential energies were monitored. The energies were defined and organized to distinguish between:

4.2.1 Strain energy in the cable,
4.2.2 Kinetic energy in the cable,
4.2.3 Kinetic energy in the load,
4.2.4 Potential energy of the cable, and
4.2.5 Potential energy of the load.

These were all normalized with the total energy of the system as computed from initial conditions.

4.2.1 Strain energy in the cable

The strain energy during motion is computed as a summation over all elements, namely,

$$SE = \sum_{i}^{N} 1/2 \; T \gamma_o \Delta s_o \; .$$

The initial strain energy is computed from the catenary expressions as

$$SE_I = 2m \int_{\left(\frac{x}{m}\right)_{LOAD}}^{\frac{L}{2m}} 1/2 \; T \gamma_o \frac{ds}{dx} \; d\left(\frac{x}{m}\right)$$

and with

$$T = w_o m \cosh \frac{x}{m} \; ,$$

$$\gamma_o = \frac{ds}{ds_o} - 1 = \frac{T}{EA} \; ,$$

$$s = m\left(\sinh \frac{x}{m} - \sinh \left(\frac{x}{m}\right)_{LOAD}\right) \; , \quad \text{and}$$

$$\frac{ds}{dx} = \cosh \frac{x}{m} \; .$$

Where m is the catenary parameter equal to horizontal tension over line weight per foot, this becomes

$$SE_I = m \int_{\left(\frac{x}{m}\right)_{LOAD}}^{\frac{L}{2m}} \frac{(\omega_o m)^2 \ cosh^3 \frac{x}{m}}{EA} \, d\left(\frac{x}{m}\right)$$

or

$$SE_I = \frac{m}{4} \frac{(\omega_o m)^2}{EA} \left(1/3 \ sinh \ (3\frac{x}{m}) + 3 \ sinh \ (\frac{x}{m})\right) \Bigg|_{\left(\frac{x}{m}\right)_{LOAD}}^{\frac{L}{2m}}$$

4.2.2 Kinetic energy in the cable

This energy is computed as

$$(KE)_{CABLE} = \sum_{i}^{N} 1/2 (\frac{\omega_o}{g}) \ \Delta s \ (\dot{v}_i^2 + \dot{w}_i^2) \ .$$

The initial conditions of the examples have no kinetic energy.

4.2.3 Kinetic energy in the load

This is simply computed as

$$(KE)_{LOAD} = 1/2 \ \frac{LOAD}{g} \ (\dot{v}^2_{LOAD} + \dot{w}^2_{LOAD}) \ .$$

4.2.4 Potential energy of the cable

The cable's potential energy is also monitored during motion. The datum plane assumed is horizontal and intersects the load point resulting when loads are gradually applied. The finite difference scheme monitors the summation over all segments

$$(PE)_{CABLE} = \sum_{i}^{N} (\omega_o \Delta s)(\Delta y_{ref} + y_{LOAD} - y_i - w_i) \ .$$

The initial potential energy is evaluated from the catenary expressions as

$$\left(PE_I\right)_{CABLE} = 2\omega_o m \int_{\left(\frac{x}{m}\right)_{LOAD}}^{\frac{L}{2m}} (\Delta y_{ref} + m \cosh \frac{x}{m} - m) \frac{ds}{dx}\, d(\frac{x}{m}) .$$

Upon integration, this becomes

$$\left(PE_I\right)_{CABLE} = 2(\omega_o m)\left[(\Delta y_{ref} - m)\sinh \frac{x}{m} + m(\frac{\sinh \frac{2x}{m}}{4} + \frac{x}{2m})\right]\Bigg|_{\left(\frac{x}{m}\right)_{LOAD}}^{\frac{L}{2m}}$$

4.2.5 Potential energy of the load

The potential energy of the load is simply

$$(PE)_{LOAD} = (LOAD)(\Delta y_{ref} - w_{LOAD})$$

during motion and

$$\left(PE_I\right)_{LOAD} = (LOAD)(\Delta y_{ref})$$

initially.

The total initial energy for each example is

$$TE_I = SE_I + \left(PE_I\right)_{CABLE} + \left(PE_I\right)_{LOAD} .$$

This is used to normalize the other energies resulting in definition of the following ratios,

$$se = \frac{SE}{TE_I} ,$$

$$pe = \frac{(PE)_{CABLE} + (PE)_{LOAD}}{TE_I} , \text{ and}$$

$$ke = \frac{(KE)_{CABLE} + (KE)_{LOAD}}{TE}$$

These ratios are plotted and discussed.

4.3 Finite Difference Routine

The finite difference routine described previously was implemented in FORTRAN IV on the University of Washington's CDC 6400. The initial segment length to be used in the examples was established during program development. A segment length of 51.5 feet seemed to provide the necessary accuracy. The time increment was established from the relationship

$$\Delta t \leq \Delta s \sqrt{\frac{\rho}{E}} \ .$$

A time step of .01/3 second was used except where indicated in the study of energy.

5.0 DISCUSSION OF RESULTS

The behavior of tensions over a 10-second period is plotted for both examples in figure 10. The vertical deflection of the load point and the horizontal deflection of a point midway between the load and the right anchor are plotted in figures 11 and 12, respectively.

Figure 10 demonstrates the need for this study. Accepted design procedures would have sized the cable for the 5,000-pound case to withstand 44,580 pounds of tension (three times the tension in the final static state). Under these conditions, this cable would have broken.

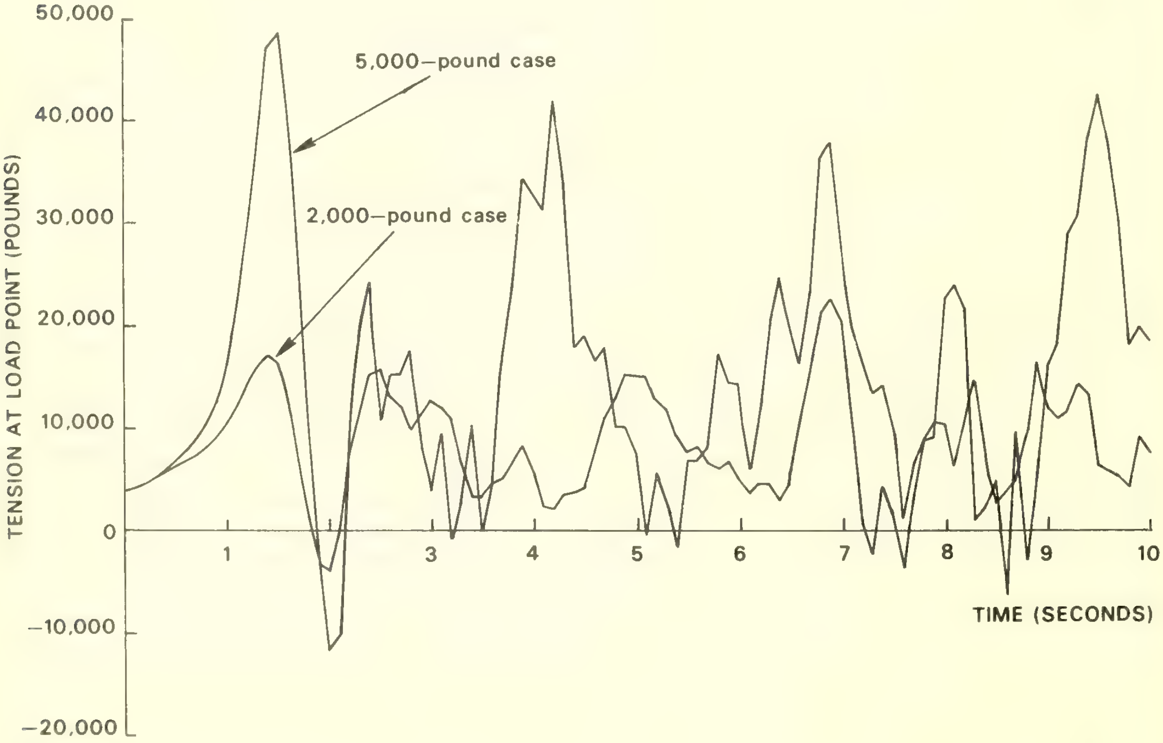


Figure 10.—Comparison of load point tensions.

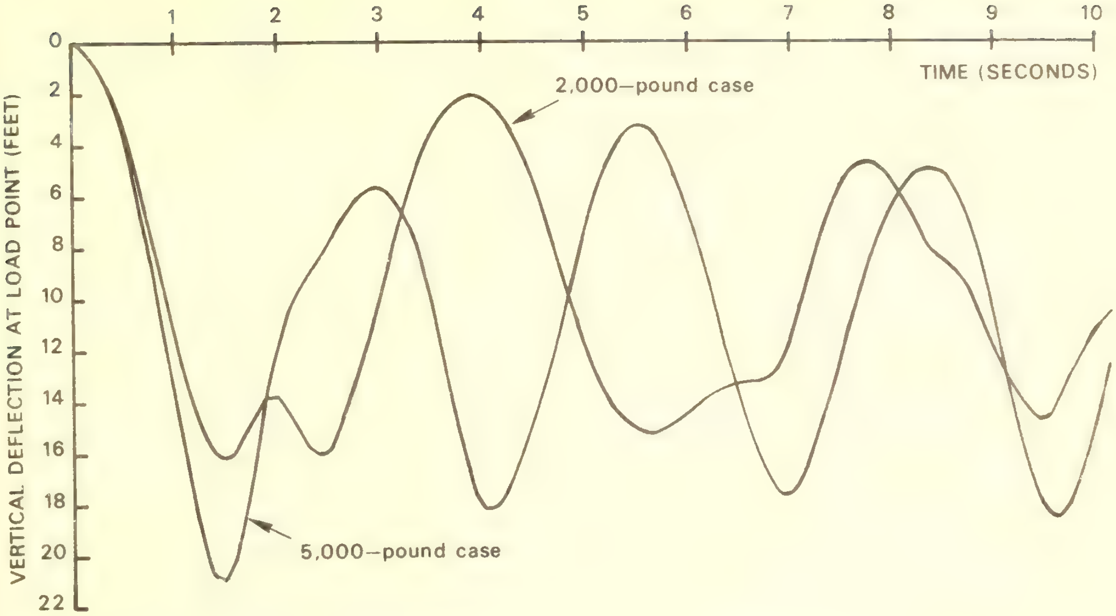


Figure 11.–Comparison of load point vertical deflections.

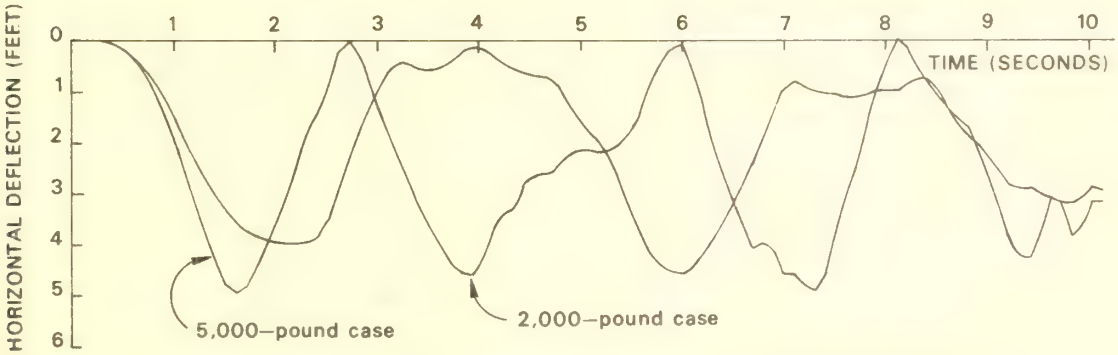


Figure 12.–Comparison of horizontal deflections (monitored midway between the load and the right anchor).

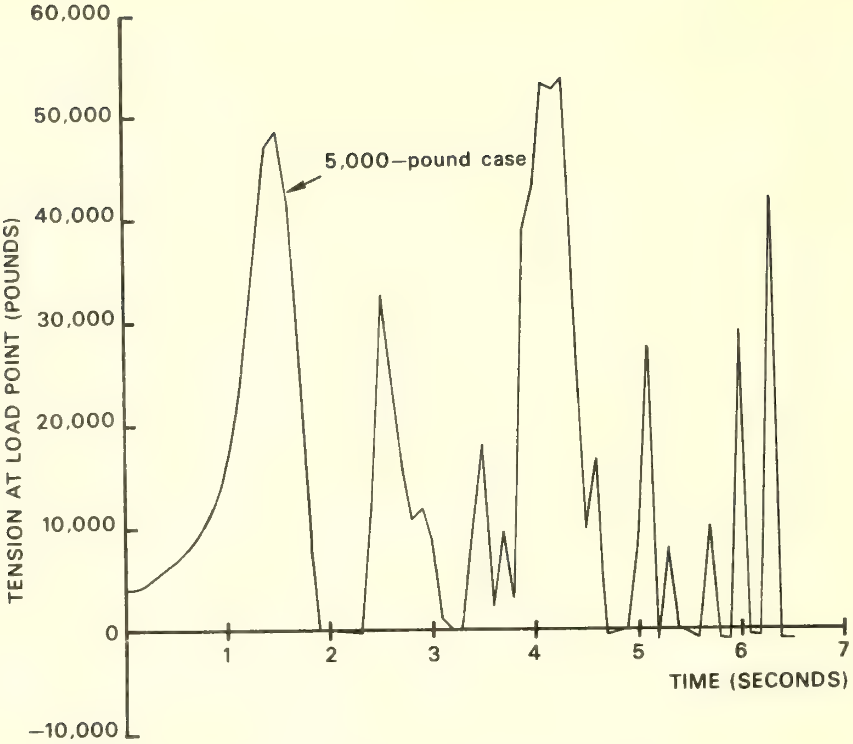


Figure 13.—Tension in compression-limited case.

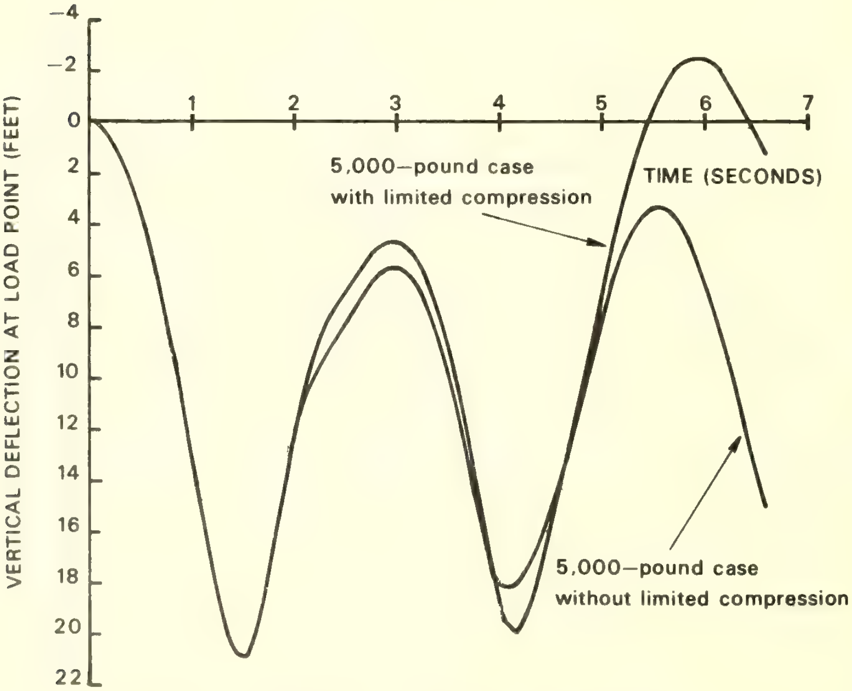


Figure 14.—Comparison of load point vertical deflections.

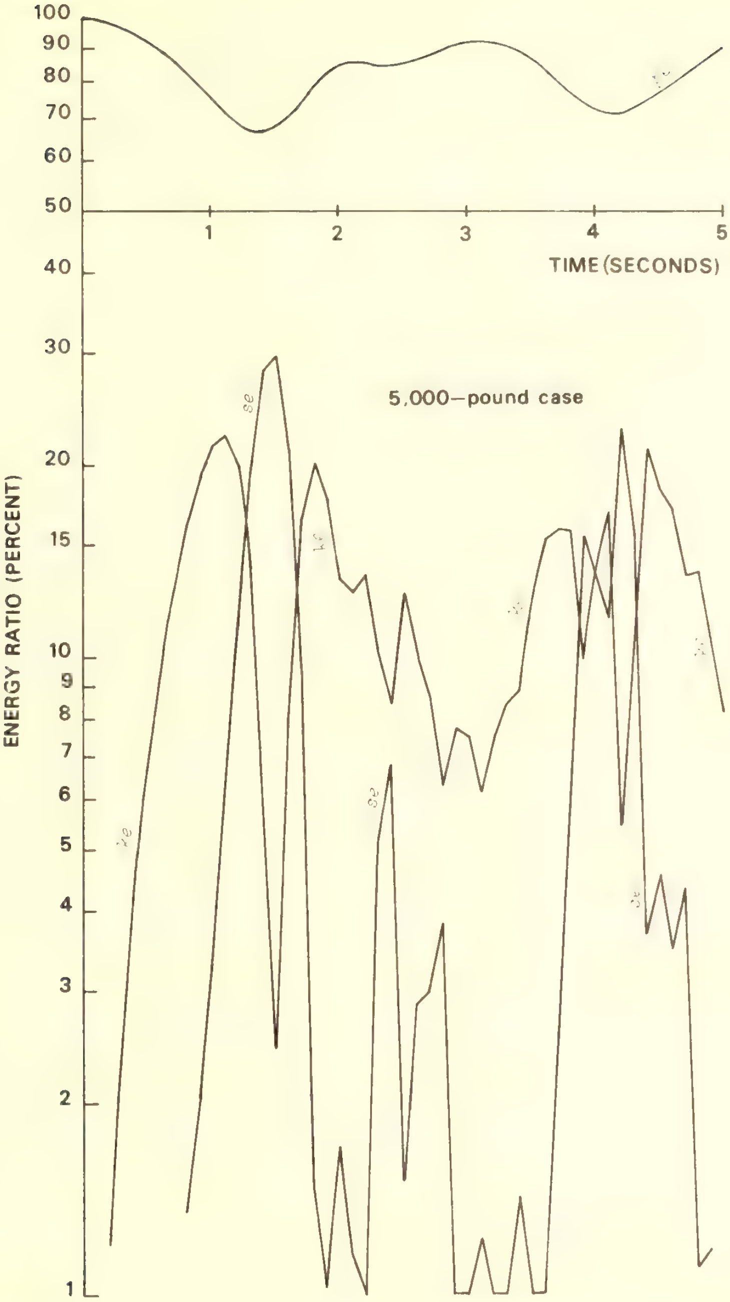


Figure 15.—Comparison of energy ratios.

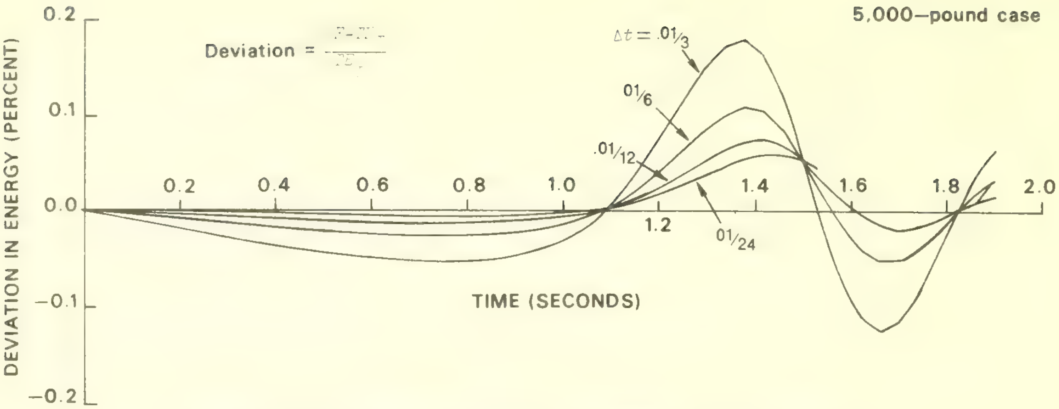


Figure 16.—Energy deviations with different time increments.

Although the relatively uniform behavior of the deflection curves suggests that an analytic prediction might be possible, the deflection response is deceptive as an indicator of tensions. This is apparent since the erratic behavior of the tension is not clearly indicated by the deflections. The deflections, however, may serve to predict the upper bound on tensions. For example, the 20.8-foot deflection in the 5,000-pound case would imply a 21,100-pound load, causing 48,300 pounds of tension. The peaks occurring later do not reach this level of tension since at these points more energy is in kinetic form.

The tensions displayed in figure 10 were allowed to experience negative values (compression) to maintain stability in the computations. Figure 13 shows the 5,000-pound case, limited to a physically more realistic maximum of 1,000 pounds compression, which generated instabilities that were out of control by 6.5 seconds. Again, the response of vertical deflection, compared in figure 14 to the 5,000-pound case allowing compression was deceptive. This situation is presently the major problem in the analysis. Bending resistance, introduced in an attempt to solve this problem, also failed to control the situation.

Strain, kinetic, and potential energy distributions are displayed in figure 15. The uniform behavior of the potential energy could be expected since the vertical deflection response is also uniform. The erratic behavior of the strain and kinetic energies are comparable to the tension response. These fluctuations are probably the major cause of the variations in the total energy plotted in figure 16. It is clear that smaller time increments reduce the fluctuations in total energy.

6.0 CONCLUSION

A study of previous work done in the area of cable dynamics has revealed very little that is applicable to the skyline logging problem. The configurations and loading conditions experienced by the logging skyline distinguish it as a unique problem in cable dynamics. The preliminary results presented in this note clearly point out the need for further study. This work should continue on an analytical basis until a reliable simulation model can be formed. Eventually an experimental program to aid in model development and checkout should be conducted.

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CHEMICAL CHARACTERISTICS OF SOME FOREST AND GRASSLAND SOILS OF NORTHEASTERN OREGON. I. RESULTS FROM REFERENCE PROFILE SAMPLING ON THE STARKEY EXPERIMENTAL FOREST AND RANGE

by

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and

Gerald S. Strickler, *Plant Ecologist*

ABSTRACT

Chemical analyses of single profiles of six soil series on the Starkey Experimental Forest and Range were made to begin quantification of the soil resources in the Blue Mountains of northeastern Oregon.

Among the forest soils, available phosphorus was consistently much higher in the Tolo profiles while organic matter and total nitrogen values were found to be comparatively low. Couse and Klicker soils had higher levels of total exchangeable cations than did the Tolo soils.

Only minor differences were noted among grassland soils. However, the Rock Creek soil did appear to be quite low in available P, lowest of all the surface samples in both forest and grassland profiles.

INTRODUCTION

Published information on mountainous forest and associated grassland soils in eastern Oregon is primarily descriptive in nature, covering either general areas (Tarrant 1956, Anderson 1956) or specific resource areas,[1] (Driscoll 1964, Strickler 1965). Information concerning the chemical characteristics of these soils is meager (Youngberg and Dyrness 1964) although some unpublished information exists.

The need for information on chemical characteristics of soils is not new but is rapidly increasing because of ever greater emphasis on optimizing productivity of forest and range lands. The multiple use program on National Forests often requires identification of productive potentials of landscapes for several products. Knowledge of soil chemical properties is essential for determining such potentials.

The overall objective of this study is the collection of soil chemical data which will characterize the fertility status of forest and grassland soils of northeastern Oregon and southeastern Washington. Seven individual profiles of six soil series were analyzed in this initial phase of the study. The seven profiles included several used as references in the soil survey of the Starkey Experimental Forest and Range[2] and other representative profiles on the Starkey.

In the Grande Ronde River drainage basin, various phases of the six series sampled occur on about 60 percent of a total of 3.17 million acres (Oregon State Water Resources Board 1969). Some classification characteristics of the sampled series are given in table 1.

STUDY AREA

The Starkey Experimental Forest and Range is located 30 miles southwest of La Grande, Oregon, on the main crest of the central Blue Mountains--an uplifted, faulted, and dissected formation of tertiary basalts. Elevations range between 3,800 and 5,000 feet. The climate is subhumid to semiarid with mean annual precipitation of 20 inches received as winter snows and spring and fall rains. The mean growing season on the soils studied ranges between 85 and 105 days, but frost can occur in any month.

Strickler (1965) described the associated vegetation on the Starkey. Forested soils commonly have an open to dense overstory of ponderosa pine *(Pinus ponderosa)* and Douglas-fir *(Pseudotsuga menziesii* var. *glauca)* on the Klicker and Couse series and Douglas-fir, grand fir

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[1] E. W. Stevenson. Preliminary study of soils on the Starkey Experimental Forest and Range. Mimeographed, 12 p., 1950.

[2] Soil Survey, Starkey Experimental Forest and Range, Union and Umatilla Counties, Oregon. Soil Conserv. Serv. and Pac. Northwest Forest & Range Exp. Sta., USDA Forest Serv. Mimeographed, 32 p., 1960.

Table 1.--*Characteristics of six soil series on the Starkey Experimental Forest and Range*[1]

Series	Subgroup	Family	Parent material	Example profile sequence	Depth
					Centimeters
Tolo	Typic Vitrandepts	Ashy over loamy, mixed frigid	Volcanic ash[2] over basalt or buried soil	A1-AC-C-IIB21b-IIB22b-R	50-150
Klicker	Typic Argiudolls	Fine-loamy, mixed frigid	Basalt and loess	A1-A3-B1-B21t-B22t-R	40-75
Couse	Typic Haploxerolls	Fine-silty, mixed frigid	Loess and basaltic alluvium	A1-B21-B22-IIA2b-IIB21b-IIB22b-IICb	90-170
Rock Creek	Lithic Argixerolls	Loamy skeletal, mixed mesic	Basalt and loess	A1-B2-R	5-40
Ukiah	Vertic Argixerolls	Fine, montmorillonitic, mesic	Mixed sedimentary	A1-A3-B1-B2-B3-C1-C2m	50-75
Albee	Typic Haploxerolls	Loamy, mixed frigid	Basalt and loess	A1-B1-B2-R	50-75

[1] Soil classification information (except Albee series) from: Placement of Series, West Region. USDA Soil Conserv. Serv., 229 p., 1968. Albee series classification: Arnold Ness, State Soil Correlator, Soil Conserv. Serv., Portland, Oreg., personal communication. Example profile sequence and depth data from: Soil Survey, Starkey Experimental Forest and Range, Union and Umatilla Counties, Oregon. Soil Conserv. Serv. and Pac. Northwest Forest & Range Exp. Sta., USDA Forest Serv. Mimeographed, 32 p., 1960.

[2] The Tolo series is currently being revised into two series, one having volcanic ash over basalt bedrock and the other having ash over a buried B horizon which was developed from basalt (Grant Lindsay, Soil Conserv. Serv., Baker, Oreg., personal communication).

(Abies grandis), western larch *(Larix occidentalis)*, and lodgepole pine *(Pinus contorta)* on the Tolo series. The understory consists of various shrubs, forbs, and grasses dominated by pinegrass *(Calamagrostis rubescens)* and elk sedge *(Carex geyeri)*. On grassland soils, Sandberg bluegrass *(Poa sandbergii)*, onespike danthonia *(Danthonia unispicata)*, and, on the deeper profiles, scattered bluebunch wheatgrass *(Agropyron spicatum)* characterize the Rock Creek series. Idaho fescue *(Festuca idahoensis)* and bluebunch wheatgrass dominate the plant composition of Ukiah and Albee soils.

METHODS

Soil samples were collected in the following depth increments: 0-15 cm., 15-30 cm., 30-60 cm., 60-90 cm., and 90-120 cm. In some cases, rock prevented reaching the maximum depth. Samples were air dried after collection, passed through a 2-mm. sieve, and stored in plastic bags. Samples were analyzed for the following: total nitrogen by the Kjeldahl method (Jackson 1958, p. 187-190), organic matter by the Walkley-Black method (Jackson 1958, p. 219-221), extractable sodium and potassium by flame photometer, and extractable calcium and magnesium by versenate titration (U.S. Salinity Laboratory Staff 1954, p. 94-95). Extraction of all exchangeable cations followed the centrifugation method (U.S. Salinity Laboratory Staff 1954, p. 100-101). Available phosphorus was determined by sodium bicarbonate extraction (Olsen et al. 1954) modified according to the Murphy and Riley method discussed by Watanabe and Olsen (1965),[3] and soil reaction in 0.01 M. $CaCl_2$.

Values for the organic carbon to nitrogen ratios were computed by multiplying the organic matter values by 58 percent (assumed carbon content) and dividing by the total nitrogen content. Calcium to magnesium ratios were calculated from the exchangeable quantities of each. Sums of exchangeable cations were calculated for comparison. Cation exchange capacity determinations were also made but were not reported due to the inconsistent results obtained from various analytical methods. This inconsistency was most pronounced in the analyses of volcanic ash derived soils and those thought to contain more than minor amounts of volcanic ash. Data for total exchangeable cations represent a very gross comparison of cation exchange capacity and are discussed in this context.

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[3] A wavelength of 810 nm. on a Coleman Junior II spectrophotometer was used in accordance with recommendations made by F. S. Watanabe, USDA, Agr. Res. Serv., Dep. Agron., Colo. State Univ., Fort Collins, Colo. (Mention of products by name does not constitute endorsement by the U.S. Dep. Agr.)

RESULTS

Chemical analyses are reported for forest soils (table 2) and grassland soils (table 3). Organic matter and total nitrogen of the upper profile and the exchangeable calcium, magnesium, and total exchangeable cations throughout the soil profile were consistently higher in the Couse and Klicker profiles than in the Tolo soils. Only available phosphorus had higher values in the Tolo soils and these values were very high. Relatively small differences were noted in pH, C/N ratios, or exchangeable sodium and potassium. Although most of the Ca/Mg ratios were in the 2/1 to 4/1 range, higher values were noted in the ash over basalt soil.

Organic matter, total nitrogen, C/N ratios, and available phosphorus decreased with increasing depth as one might expect. Abrupt changes in exchangeable calcium, magnesium, and total exchangeable cations are often related to profile features such as a clay-textured horizon or to some discontinuity such as the existence of a buried soil. Cases where the former exists are in the Couse and Klicker profiles at the 60-cm. depth. A case for the latter exists in the 90-120-cm. depth increment of the ash over buried soil.

Chemical properties of the grassland soils were similar to each other; however, in the Ukiah soil exchangeable calcium, magnesium, and total exchangeable cations show a strong increase with increasing clay content below the 30-cm. depth. This soil normally develops a dense clay horizon exhibiting prismatic structure at about 30-40 cm. Available phosphorus in the Rock Creek soil was quite low for surface soil material, lowest of all the soils studied.

Soil reaction values were about the same in both the forest and grassland soils. One will find that pH readings taken in 0.01 M. $CaCl_2$ will be from 0.5- to 0.8-pH units lower than readings taken in 1:1 or 1:2 distilled water dilutions (Black 1965, p. 919).

Calcium and magnesium appeared to be in a balanced ratio in all cases. The values at which one would expect problems related to an imbalance are not currently well defined; however, a ratio between 5/1 and 1/1 is considered most desirable (Black 1965, p. 1009).

The forest soils had higher C/N ratios than the grassland soils. This is to be expected with woodier types of organic materials as contrasted with the herbaceous materials of the grassland vegetation. Mineralization of organic nitrogen exceeds immobilization where narrow C/N ratios exist (20/1 to 30/1). The narrower the ratio, the more mineralization is favored (Alexander 1961, p. 265); hence, there should be a more rapid mineralization of nitrogen in the grassland soils in general.

Table 2.--*Chemical characteristics of forest soil profiles*

Soil series and depth increment (cm.)	Chemical properties										
	pH	Organic matter	Total nitrogen	Ratio C/N	Available P	Exchangeable cations					Ratio Ca/Mg
						K	Na	Ca	Mg	Total	
	- - - -	*Percent*	- - - - -		*P.p.m.*	- - - - -		*Meq./100 g.*	- - - - - -		
Couse:											
0-15	5.5	6.52	0.21	18/1	12.6	0.7	0.2	21.1	7.8	29.8	2.7/1
15-30	5.5	6.61	.22	17/1	8.2	.4	.3	18.9	6.0	25.6	3.2/1
30-60	5.3	1.82	.08	13/1	4.8	.5	.4	17.0	7.8	25.7	2.2/1
60-90	5.4	.94	.04	14/1	2.6	.5	.7	25.5	12.5	39.2	2.0/1
90-120	6.6	.40	.02	12/1	2.4	.4	.9	29.5	14.5	45.3	2.0/1
Klicker:											
0-15	5.6	6.01	.18	19/1	22.1	1.5	.1	15.6	5.5	22.7	2.8/1
15-30	5.5	3.07	.11	16/1	21.0	.8	.1	13.7	5.5	20.1	2.5/1
30-60	5.6	1.47	.06	14/1	10.6	.8	.2	14.4	7.7	23.1	1.9/1
60-75	5.5	1.02	.04	15/1	11.7	.7	.2	17.3	9.6	27.8	1.8/1
Tolo[1] (ash over basalt):											
0-15	5.4	2.70	.08	20/1	53.8	1.1	.1	5.2	1.1	7.5	4.7/1
15-30	5.6	1.29	.05	15/1	32.0	1.2	.1	5.8	.8	7.9	7.0/1
30-60	5.6	.83	.03	16/1	23.2	1.2	.1	6.0	.7	8.0	8.1/1
60-81	5.5	.79	.03	15/1	24.7	1.0	.2	5.6	.7	7.5	7.5/1
Tolo (ash over buried soil):											
0-15	5.8	2.12	.07	18/1	46.2	1.4	.0	6.5	1.9	9.8	3.5/1
15-30	5.6	1.07	.04	16/1	32.2	1.4	.1	5.3	1.5	8.3	3.7/1
30-60	5.4	.65	.03	13/1	29.0	1.3	.1	4.4	1.0	6.8	4.4/1
60-90	5.5	.60	.02	18/1	10.8	.8	.1	4.7	1.6	7.2	2.9/1
90-120[2]	5.5	.51	.03	10/1	11.3	.8	.2	9.4	4.5	14.9	2.1/1

[1] Type location (benchmark profile) for this series.

[2] The 90-cm. depth corresponds roughly to the upper boundary of a buried B horizon.

Table 3.--*Chemical characteristics of grassland soil profiles*

Soil series and depth increment (cm.)	Chemical properties										
	pH	Organic matter	Total nitrogen	Ratio C/N	Available P	Exchangeable cations					Ratio Ca/Mg
						K	Na	Ca	Mg	Total	
	- - - - - *Percent* - - - - -				*P.p.m.*	- - - - - - - *Meq./100 g.* - - - - - -					
Albee:											
0-15	5.7	3.37	0.16	12/1	16.0	0.9	0.1	10.6	3.0	14.6	3.6/1
15-30	5.7	1.78	.10	10/1	6.8	.6	.1	10.0	3.2	13.9	3.2/1
30-65	5.5	1.49	.09	10/1	10.0	.5	.1	9.7	3.4	13.7	2.9/1
Rock Creek:											
0-13	5.3	3.75	.19	11/1	6.8	.6	.2	12.1	4.3	17.2	2.8/1
Ukiah:											
0-15	5.6	4.02	.19	12/1	16.1	1.4	.1	10.9	2.8	15.2	3.9/1
15-30	5.4	2.39	.13	11/1	8.5	.8	.1	10.6	3.6	15.1	2.9/1
30-60	5.2	1.04	.08	8/1	6.2	.9	.3	16.5	7.7	25.4	2.1/1
60-71	5.0	.56	.04	8/1	4.1	.8	.5	30.2	16.8	48.3	1.8/1

Available phosphorus values of the grassland soils were similar to those of the Couse and Klicker forest soils. Perhaps the high levels of phosphorus in the ash soils are caused by phosphorus fixation by allophanic materials. No growth response to phosphorus additions would be expected on any of the soils with the exception of the Rock Creek profile. A response is generally unlikely above analysis values of 10 p.p.m. available P (Black 1965, p. 1046).

Exchangeable potassium values above 0.5 meq./100 g. are in the adequate to high range of available plant potassium. All of the soils appear to contain adequate potassium. Exchangeable sodium levels are low and do not present any toxicity problems. The dominance of calcium and magnesium on the exchange complex is common; no deficiencies of either of these elements would be expected.

Some unpublished data are available for comparison with three of the soils studied. Youngberg and Dyrness (1964) reported chemical analyses by horizon for a Tolo soil in central Oregon. They reported higher values for organic matter and total nitrogen content in the surface soil (9.17 percent and 0.19 percent, respectively). Exchangeable Ca and Mg values were generally higher in the central Oregon soil (ranges of 8.3-10.4 meq. Ca/100 g., 2.9-3.4 meq. Mg/100 g.); however, available P was lower (27-12 p.p.m.), and exchangeable K was about the same. Analyses made by Pettit[4] on a Tolo soil in the Wallowa Mountain foothills of eastern Oregon showed very high available P (107-10 p.p.m.), similar levels of exchangeable K, but higher exchangeable Ca (9-13 meq./100 g.) and Mg (2-8 meq./100 g.). Other analyses of the Tolo soil over basalt on the Starkey Experimental Forest and Range made by Moore[5] also showed higher Ca and Mg levels.

Comparison of the data from the Klicker soil analyses with those made by the Soil Conservation Service on two profiles sampled on the Starkey showed very similar results.[6] One of the Klicker profile analyses reported in the Lincoln survey was apparently for the same profile sampled by the authors.

Hedrick et al. (1965, p. 41) reported some chemical analyses of a Couse profile in the foothills of the Wallowa Mountains. Their results were essentially the same for pH (allowing for methodology differences);

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[4] R. D. Pettit. Effects of seeding and grazing on a clearcut burn in a mixed-coniferous forest stand of the Wallowa Mountain foothills. Diss., Oreg. State Univ., 133 p., 1966.

[5] Duane Moore, Forest. Sci. Lab., Forest Serv., Corvallis, Oreg., personal communication.

[6] Lincoln Soil Survey Laboratory Report for Soils Sampled in Union County, Oregon. Lab. Staff, Soil Surv. Lab., Soil Conserv. Serv., USDA., Lincoln, Nebr. Unpublished report, 48 p.

organic matter values were somewhat lower in the upper 30 cm. (4.23 percent, 0-15 cm.; 2.23 percent, 15-30 cm.) but similar below 30 cm. The surface soil nitrogen content was reported as 0.19 percent which was essentially the same. Available phosphorus was higher throughout the profile, ranging from 27 p.p.m. in the upper 15 cm. to 4 p.p.m. at 100 cm.

The importance of the differences between results cited in the literature and the results reported herein may not be readily apparent. Certainly the differences due to sampling technique (horizon vs. fixed depth) have an effect on magnitudes of the numbers reported; however, these should be reconciled with weighted averages if the soils are similar in all respects. Instead, the differences are probably due to the combined effects of differing soil forming factors (climate, vegetation, etc.). One will find that considerable variability is allowed in many soil series in both chemical and physical characteristics. Hence, a single profile analysis cannot be considered wholly representative of its parent series, and the reader is cautioned in the use of these results. Youngberg and Dyrness (1964) noted sizable differences among soil nitrogen values in a Lapine series under different plant communities. Indeed, it would not be unusual to find greater differences between analytical values within a single soil series than among different series. Future analytical results should reveal the ranges in chemical characteristics to be expected within each series as related to vegetational, geographic, and other gradients.

SUMMARY

Chemical analyses of single profiles of six soil series on the Starkey Experimental Forest and Range were made to begin quantification of the soil resources in northeastern Oregon. Although these results are considered to be fragmentary in relation to all occurrences of these series, several notable differences were found.

Among the forest soils, available phosphorus was consistently much higher in the Tolo profiles while organic matter and total nitrogen values were found to be comparatively low. Couse and Klicker soils had higher levels of total exchangeable cations than did the Tolo soils.

Only minor differences were noted among grassland soils. However, the Rock Creek soil did appear to be quite low in available P, lowest of all the surface samples in both forest and grassland soils.

Many analyses yielded similar results among all soils studied. Exchangeable K, Na, Ca, and Mg showed similar trends with increasing soil depth, as did organic matter and total nitrogen. Calcium to magnesium ratios and pH values were similar for all soils; however, forest soils exhibited consistently higher C/N ratios than grassland soils at all soil depths. Future analyses of soils sampled at other locations will lend insight into the variability of these chemical properties within these and other soil series.

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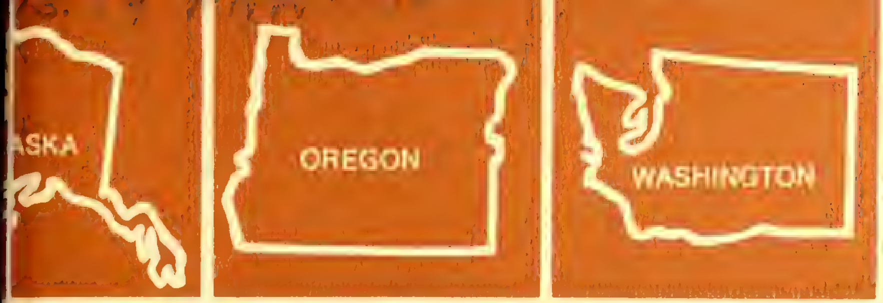

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A Checklist of Vascular Plants on the H. J. Andrews Experimental Forest, Western Oregon

by

Jerry F. Franklin, *Principal Plant Ecologist*

and

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This publication is a Forest Service contribution to the International Biological Program, Coniferous Forest Biome.

Keywords: Vascular plants, tracheophytes, plant ecology, H. J. Andrews Experimental Forest, Oregon.

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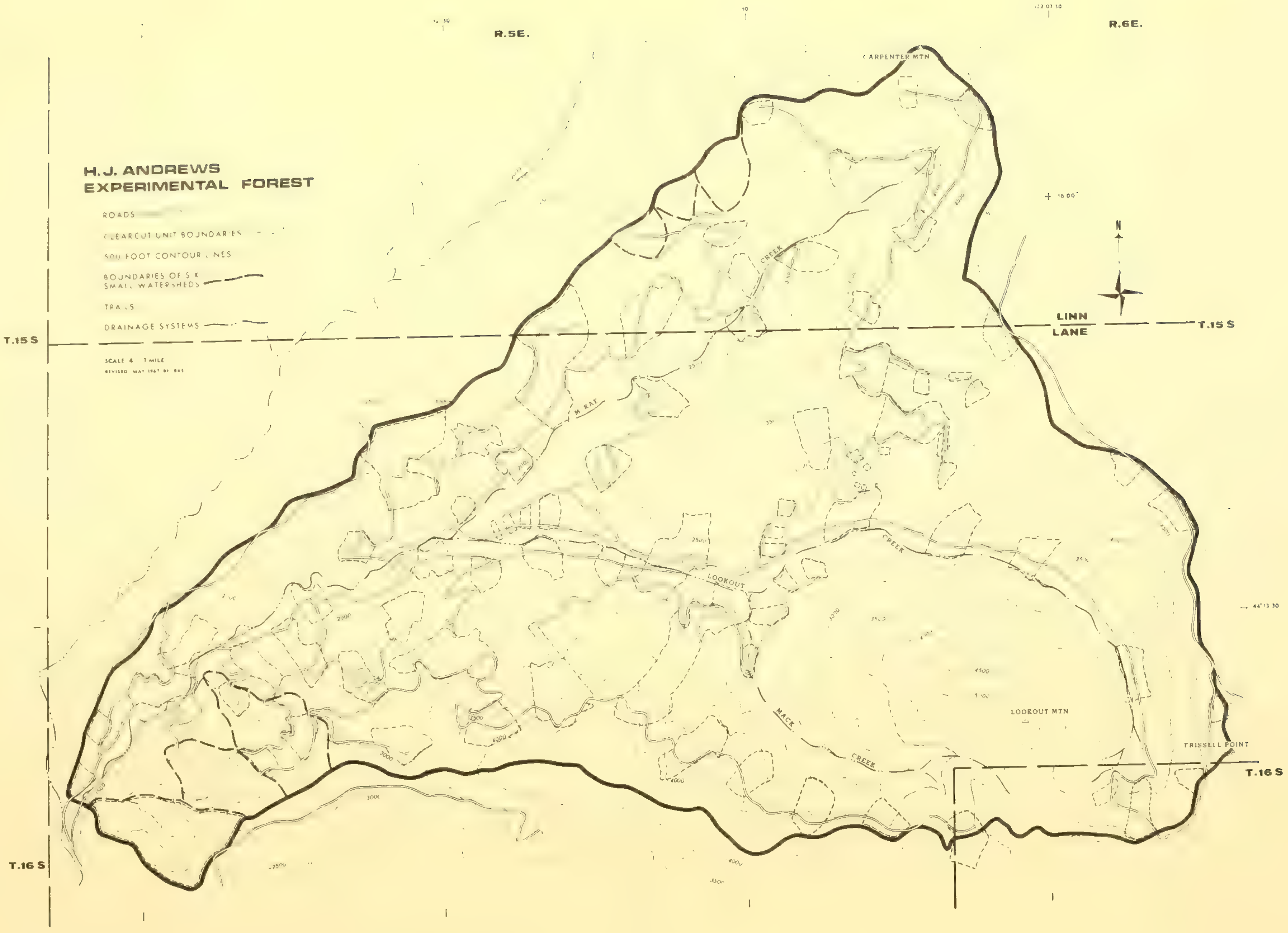

Figure 1.--*Map of H. J. Andrews Experimental Forest showing roads, clearcut unit boundaries, 500-foot contour lines, and other topographic features.*

ABSTRACT

Lists 480 plant taxa which have been encountered in the 6,000-hectare Lookout Creek drainage of west-central Oregon. Notes on habitats and abundance are included for most taxa.

The H. J. Andrews Experimental Forest occupies the 6,000-hectare drainage of Lookout Creek, a tributary of the McKenzie River, on the western slopes of the Oregon Cascade Range in west-central Oregon (fig. 1). This experimental forest has been administered by the U.S. Forest Service for scientific and educational purposes since its establishment in 1948. It is an active center for watershed, timber management, and ecological research programs of the Pacific Northwest Forest and Range Experiment Station and the Coniferous Forest Biome's Analysis of Ecosystems Project in the International Biological Program. This checklist of vascular plants encountered on the forest during the first 20 years of its existence will assist scientists working on the forest, and other interested visitors, in plant identification.

ENVIRONMENT

The H. J. Andrews Experimental Forest is mountainous with climate, soils, topography, and bedrock geology typical of the Western Cascades, the older Oligocene-Miocene segment of the Oregon Cascade Range. Lookout Creek is a headwaters drainage with geologically mature topography (fig. 1). Well-defined drainages, sharp ridges, and steep slopes are common except at higher elevations, where areas of gentle, undulating topography are common. All rock formations are volcanic in origin, with tuffs, breccias, and basalts common at lower elevations and andesite on the ridges. These formations typically belong to the Little Butte Volcanic Series and, with increasing elevation, to the Sardine and Cascade Andesite formations. Major soil groups are Reddish-Brown Lateritics and Brown Podzolics, which are typically moderately deep and fine textured. Deep colluvial soils are common at lower elevations and soils from volcanic ash, on higher ridges.

The climate of the experimental forest is maritime, with a pronounced dry summer season. Annual precipitation varies from about 2,300 millimeters at lower elevations to 2,800 millimeters or more on the high ridges. About 90 percent of this falls from October through April, and the June through August period is typically very dry. At elevations above 900 meters, winter snowpacks accumulate to a depth of 1 meter or more. Temperatures are moderate with mean July maxima of around 29° C. and January minima of around -3° C. Temperature and moisture combine to produce an excess of potential evapotranspiration over precipitation from about mid-May to September (Rothacher, Dyrness, and Fredriksen 1967).

COMMUNITIES AND PLANT HABITATS

The distribution of the taxa included in this checklist is related to the vegetative zones found on the H. J. Andrews Experimental Forest and the successional stages of the plant communities found within each zone, e.g., recently clearcut areas and old-growth forests. A number of special plant habitats and communities, such as riparian and bog types, will be noted, since many species are found only in these locations.

There are two major vegetative zones on the experimental forest based on climax forest types (Franklin and Dyrness 1969): (1) the *Tsuga heterophylla* (TSHE) zone, and (2) the *Abies amabilis* (ABAM) zone. These are roughly comparable to Merriam's Humid Transition and Canadian Life Zones. Scattered stands of *Tsuga mertensiana* are found at the highest elevations in the forest. However, because of their fragmented nature, these areas are not considered representative of the true TSME zone (a zone which approximates the Hudsonian Life Zone), but rather are included within the ABAM zone.

The *Tsuga heterophylla* (TSHE) zone occurs from the lowest part of Lookout Creek (400 meters) to about 1,050 meters. Mature forests are dominated by *Pseudotsuga menziesii* with varying mixtures of *Tsuga heterophylla* and *Thuja plicata*. There is a broad spectrum of forest communities associated with a moisture gradient within this zone. The *Pseudotsuga menziesii/Holodiscus* association is found on the warmest and driest sites with *Pseudotsuga* the major climax species. With increasing moisture, the *Pseudotsuga-Tsuga heterophylla/Corylus cornuta, Tsuga/Castanopsis chrysophylla-Rhododendron macrophyllum, Tsuga/Rhododendron, Tsuga/Berberis nervosa, Tsuga/Polystichum munitum,* and *Tsuga/Polystichum-Oxalis oregana,* or their seral associates, are encountered. *Tsuga heterophylla* is the major climax species in all except the driest of the associations in this zone.

The *Abies amabilis* (ABAM) zone is found at higher elevations, generally over 1,050 meters. Old-growth forests in this zone are generally dominated by *Abies amabilis* and *Tsuga heterophylla,* although in some areas large, old *Pseudotsuga menziesii* may be dominant. Apparently largely as a result of fires, many stands in the ABAM zone are composed of trees in the younger age classes (100-125 years old). These second-growth stands are most often dominated by *Abies procera*. Other tree species frequently present in the zone include *Tsuga mertensiana* (over 1,350 meters), *Pinus monticola,* and *Abies grandis*. Only a limited number of forest communities have been described within the ABAM zone. At high elevations, sites having the lowest productivity are generally occupied by the *Tsuga mertensiana/Xerophyllum tenax* community. Other communities, listed in order of increasing site productivity, include *Abies amabilis/Achlys triphylla, Abies/Vaccinium alaskanse,* and *Abies/*herb. The latter community, found on moist, rich sites, is characterized by abundant cover of such herbs as *Tiarella unifoliata, Smilacina stellata, Cornus canadensis,* and *Clintonia uniflora.*

The H. J. Andrews Experimental Forest was virtually undisturbed until 1950, when logging and road construction began. Logging in the area has been of two types: (1) salvage logging in which scattered decadent trees are harvested from old-growth stands adjacent to roads; and (2) clearcut logging where all trees are removed from areas ranging from about 4 to 16 hectares in size. Following logging, these clearcut units are generally broadcast-burned to eliminate logging slash. In the ensuing 20 years, 91 clearcut units have been logged, totaling 856 hectares, or approximately 14 percent of the total forest area. Thus, clearcut areas undergoing secondary succession range from 1 to 20 years in age and occupy a number of diverse sites (fig. 1). Road rights-of-way are also important in providing routes for plant migration in the forest. Road mileage now totals about 40, and rights-of-way occupy almost 2 percent of the total area.

Specialized habitats existing on the forest include rock outcrops, mountain meadows, small bogs, and riparian zones. Rock outcrop areas, although numerous, are small and scattered throughout the forest over a wide range in elevation. Meadow openings are generally confined to ridge-top positions at elevations of 1,200 to 1,350 meters and often ringed by stands of *Abies lasiocarpa.* These rock outcrops and meadows offer a diversity of microhabitats and provide refuge for many plant species unable to compete elsewhere (Hickman 1968). Plant collections have been made in several bog areas which are situated over a considerable range in elevation. The most interesting boggy area, taxonomically, has been one at the head of Mack Creek near the summit of Lookout Mountain. Riparian zones are probably the most extensive of all specialized habitats, as it is estimated that approximately 100 miles of perennial stream channel exist on the forest. Finally, there are extensive areas of *Alnus sinuata*-dominated communities within the ABAM zone which occupy areas of heavy snow accumulation and impeded drainage.

Intensive plant collecting on the forest began in 1958 and most has been carried out by the authors and Dr. James Hickman. Voucher specimens have been obtained for the majority of species listed and, in most cases, are on file at both the Oregon State University Herbarium and the U.S. Forest Service Herbarium in Fort Collins, Colo. In addition, most collections are also represented in a small working herbarium maintained at the H. J. Andrews Experimental Forest headquarters in Blue River, Oregon. Abbreviations used in identifying plant collectors are as follows:

F - Jerry F. Franklin, U.S. Forest Service
D - C. T. Dyrness, U.S. Forest Service
F&D - Franklin and Dyrness, U.S. Forest Service
M - Ross C. Mersereau, Jr., U.S. Forest Service
H - James C. Hickman, Washington State University, Pullman, Washington

Taxa for which no collection numbers are listed were identified in the field by the authors or are reported as being present by other workers. We would like to especially acknowledge the assistance of Dr.'s F. J. Hermann and Charles Feddema of the U.S. Forest Service Herbarium, who made many of the original identifications, and Mrs. LaRea Dennis Johnston and Dr. Kenton Chambers at the Oregon State University Herbarium, who assisted with many difficult identification problems.

Nomenclature follows the most recent taxonomic manuals available as follows: Most herbs and shrubs--*Vascular Plants of the Pacific Northwest*, vols. 1-5, by C. L. Hitchcock, et al. (1955-69); trees and a few of the shrubs--*Checklist of Native and Naturalized Trees of the United States (Including Alaska)*, by E. L. Little, Jr., (1953); and nomenclature for taxa not covered in Hitchcock et al. follows *"A Manual of the Higher Plants of Oregon,"* 2d ed., by Morton E. Peck (1961). Common names provided, except for trees and a few shrubs which follow Little (1953), follow a variety of sources, the most important being Peck (1961) and Garrison, Skovlin, and Poulton (1967).

The following listing includes 480 plant taxa. Of these, 135 are generally found only in the TSHE zone, 175 are characteristic of the ABAM zone, and 170 occur in both zones. Where the habitat or abundance of a taxon or both are believed adequately known they are indicated; where they are poorly known the collection site is usually indicated.

LYCOPODIOPHYTA

Lycopodiaceae

Lycopodium clavatum L., ground- or running-pine, elk moss. Rare in dense conifer forest, ABAM zone.

Selaginellaceae

Selaginella densa Rydb. var. *scopulorum* (Maxon) Tryon, Rocky Mountain selaginella. Occasional to common in dry, open areas, especially on outcropping rock or in crevices, ABAM zone.

Selaginella wallacei Hieron., Wallace's selaginella. Common in dry, rocky areas, both zones. [F&D 145]

EQUISETOPHYTA

Equisetaceae

Equisetum arvense L., common horsetail. Occasional in wet areas, both zones. [F&D 37]

Equisetum telmateia Ehrh. var. *braunii* (Milde) Milde, giant horsetail. Common in wet areas, TSHE zone. [F 47]

POLYPODIOPHYTA

Ophioglossaceae

Botrychium multifidum (Gmel.) Trevis., leathery grape-fern. Collected in bog on Lookout Mountain, ABAM zone. [F 645]

Botrychium virginianum (L.) Swartz, Virginia grape-fern. Collected in swamp, TSHE zone. [F&D 178]

Polypodiaceae

Adiantum pedatum L., maidenhair-fern. Common, streamsides and wet forests, TSHE zone.

Athyrium filix-femina (L.) Roth, lady-fern. Occasional to abundant, streamsides, moist forests, and swamps, both zones.

Blechnum spicant (L.) With., deer-fern. Occasional to abundant, streamsides, moist forest, and swamps, both zones.

Cheilanthes gracillima D.C. Eat., lace-fern. Occasional, rocky outcrops, both zones. [F 402, F&D 146]

Cryptogramma crispa (L.) R. Br. ex Hook. var. *acrostichoides* (R. Br.) C. B. Clarke, parsley-fern. Common, rock outcrops, both zones. [F 401, F&D 229]

Cryptogramma densa (Brackenr.) Diels, Oregon cliff-brake. Occasional, on Lithosols or under boulders on exposed south slopes, ABAM zone. [H 483-1]

Cystopteris fragilis (L.) Bernh., bladder-fern. Occasional to common, rock outcrops, both zones. [F 406, F 664]

Dryopteris austriaca (Jacq.) Woyner ex Schinz & Thell., spreading woodfern. Occasional, swamps and moist forests, TSHE zone. [F&D 59]

Gymnocarpium dryopteris (L.) Newm., oak-fern. Occasional, streamsides and moist woods. TSHE zone. [F 795]

Polypodium glycyrrhiza D.C. Eat., licorice fern. Common on rocks and trees (especially *Acer macrophyllum*) along streams, TSHE zone. [F 12]

Polypodium hesperium Maxon, occasional on south- or west-facing outcrops, Frissell Mountain, ABAM zone.

Polystichum munitum (Kaulf.) Presl, western sword-fern. Common to abundant in forests and clearcuts, TSHE zone; occasional ABAM zone. [F 539]

Polystichum munitum (Kaulf.) Presl var. *imbricans* Maxon, imbricated sword-fern. Occasional on rock outcrops, ABAM zone.

Pteridium aquilinum (L.) Kuhn var. *pubescens* Underw., bracken or western brake-fern. Occasional in forests, common to abundant on clearcuts or mountain meadows, both zones.

PINOPHYTA

Taxaceae

Taxus brevifolia Nutt., western yew. Present both zones, but common in forests and on clearcuts, TSHE zone.

Cupressaceae

Chamaecyparis nootkatensis (D. Don) Spach, Alaska-cedar. Occasional on rocky ridges and in moist forest, ABAM zone. [F 98]

Juniperus communis L. var. *montana* Ait., common juniper. Common on open, rocky slopes or ridges, ABAM zone. [F 101]

Libocedrus decurrens Torr., incense cedar. Common, dry ridges and slopes, TSHE zone; occasional in and around mountain meadows, ABAM zone. [F 723]

Thuja plicata Donn, western redcedar. Common, especially moister sites, TSHE and lower ABAM zones. [F 57, F 94]

Pinaceae

Abies amabilis (Dougl.) Forbes, Pacific silver fir. Common to abundant, ABAM zone; occasional to rare, TSHE zone. [F 659, F 798]

Abies grandis (Dougl.) Lindl., grand fir. Common along Lookout Creek, occasional in forest, TSHE zone; populations approaching intermediates between *Abies concolor* and *Abies grandis* common in forests and invading meadows, ABAM zone.

Abies lasiocarpa (Hook.) Nutt., subalpine fir. Common in and around meadows, ABAM zone.

Abies lasiocarpa (Hook.) Nutt. var. *arizonica* (Merriam) Lemm., corkbark fir. Introduced plantation in middle-elevation clearcut (L202).

Abies procera Rehder, noble fir. Common in ABAM zone.

Larix decidua x *leptolepis*, Dunkeld larch. Introduced plantation of F_2 progeny in low-elevation clearcut (B131).

Picea engelmannii Parry ex Engelm., Engelmann spruce. Not known to occur naturally; plantation in middle-elevation clearcut (L303).

Pinus contorta Dougl. ex Loud. var. *latifolia* Engelm., lodgepole pine. Rare to occasional in forest and on rock outcrops and ridges, ABAM zone. [F&D 22]

Pinus jeffreyi Grev. & Balf., Jeffrey pine. Introduced plantation on clearing near entrance (lower Lookout Creek), TSHE zone.

Pinus lambertiana Dougl., sugar pine. Occasional, mainly on dry ridges, TSHE zone.

Pinus monticola Dougl., western white pine. Occasional to common, forests and clearcuts, mainly ABAM zone.

Pinus ponderosa Laws., ponderosa pine. Rare native specimens on rock outcrops, ABAM zone; plantations on several low-elevation clearcuts (especially B134). [F&D 21]

Pinus thunbergiana Parl., Japanese black pine. Plantation on low-elevation clearcut (B131).

Pseudotsuga menziesii (Mirb.) Franco, Douglas-fir. Most abundant tree species in virgin forests and on clearcuts, TSHE and lower ABAM zones.

Tsuga heterophylla (Raf.) Sarg., western hemlock. Second most abundant tree species, TSHE and lower ABAM zones.

Tsuga mertensiana (Bong.) Carr., mountain hemlock. Common to abundant, upper ABAM zone.

MAGNOLIOPHYTA

Liliatae

Juncaceae

Juncus effusus L. var. *gracilis* Hook., common rush. Common in wet areas on clearcuts and roadbanks, TSHE and lower ABAM zones. [F 108]

Juncus ensifolius Wikst., dagger-leaved rush. Common in boggy areas, ABAM zone. [F 648, F 735, F 778, F&D 39]

Juncus mertensianus Bong., Merten's rush. Collected at spring on Carpenter Mountain, ABAM zone. [F 776]

Juncus parryi Engelm., Parry's rush. Occasional in rocky areas, ABAM zone. [F 403, F 787]

Luzula intermedia (Thuill.) Spenner, common wood-rush.[1/] Occasional on clearcuts and roadbanks, both zones. [F 23, F 429, F&D 148]

Luzula parviflora (Ehrh.) Desv., small-flowered wood-rush. Collected on wet roadbank, ABAM zone. [F&D 71]

Cyperaceae

Carex abrupta Mack., abruptly-beaked sedge. Collected in woods near Carpenter Mountain Lookout, ABAM zone. [F 339]

Carex amplifolia Boott in Hook., ample-leaved sedge. Wet areas, TSHE zone. [F&D 48]

Carex aperta Boott in Hook., Columbia sedge. Abundant in shallower parts of temporary ponds, upper TSHE and lower ABAM zones. [F 637]

Carex aquatilis Wahl., water sedge. Collected in bog on Lookout Mountain, ABAM zone. [F 733]

Carex brevicaulis Mack., short-stemmed sedge. Occasional, forest or clearcut areas, both zones. [F&D 133, F&D 155]

Carex deweyana Schw. var. *bolanderi* W. Boott, Bolander's sedge. Occasional, wet roadsides, both zones. [F 772, M 12]

Carex deweyana Schw. ssp. *leptopoda* (Mack.) Calder & Taylor, short-scaled sedge. Common, wet areas, including *Alnus sinuata* communities and swamps, both zones. [F 768, F&D 137, F&D 179]

Carex hendersonii L. H. Bailey, Henderson's sedge. Collected in forest, upper TSHE zone. [F&D 158]

Carex hoodii Boott in Hook., Hood's sedge. Common, mountain meadows, ABAM zone. [F 718, F&D 224]

Carex interior L. H. Bailey, inland sedge. Collected in swamp, TSHE zone. [F&D 170a]

Carex interrupta Boeck., green-fruited sedge. Collected in bog on Lookout Mountain, ABAM zone. [F 646]

Carex jonesii L. H. Bailey, Jones' sedge. Collected in bog on Lookout Mountain, ABAM zone. [F 730]

Carex laeviculmis Meinsh., smooth-stemmed sedge. Occasional to abundant in wet areas, clearcuts, or roadbanks, both zones. [F 108a, F 773, F&D 40, M 1]

[1/] At the recommendation of F. J. Hermann we are using *Luzula intermedia* (Thuill.) Spenner instead of *L. campestris* L. DC. which C. L. Hitchcock uses for this taxon.

Carex lenticularis Michx., lenticulate sedge. Collected at spring on Carpenter Mountain, ABAM zone. [F 780]

Carex luzulina Olney, cold-loving sedge. Common, wet areas and bogs, ABAM zone. [F 738, F 782, F&D 41]

Carex mertensii Prescott ex Bong., Merten's sedge. Occasional to common, *Alnus sinuata* communities, ABAM zone. [F&D 138]

Carex ormantha (Fern.) Mack., western stellate sedge.[2/] Collected in bog on Lookout Mountain, ABAM zone. [F 732, F&D 110]

Carex pachystachya Cham. ex Steud., thick-headed sedge. Occasional to abundant, wet areas, including swamps, clearcuts, and roadsides, both zones. [F 769, F 771, F&D 96, F&D 120, F&D 170]

Carex pensylvanica Lam. var. *vespertina* L. H. Bailey, long-stoloned sedge. Occasional to abundant, mountain meadows and forests, ABAM zone. [F 407, F 720, F&D 15, F&D 66, F&D 95, F&D 151]

Carex rossii Boott in Hook., Ross' sedge. Collected on summit of Carpenter Mountain, ABAM zone. [F 793a]

Carex rostrata Stokes ex With., beaked sedge. Collected in forest swamp, TSHE zone. [F&D 169]

Carex subfusca W. Boott in Wats., rusty sedge. Collected in swamp, lower TSHE zone. [F&D 168]

Carex vesicaria L., inflated sedge. Abundant, temporary ponds, upper TSHE zone. [F 634]

Eleocharis pauciflora (Lightf.) Link, few-flowered spike-rush. Common, boggy areas, ABAM zone. [F 728, F 781]

Eriphorum L., cotton-grass. Collected on wet roadbank, ABAM zone. [F 649]

Scirpus microcarpus Presl, small-fruited bulrush. Common, swamps and bogs, upper TSHE and ABAM zones. [F 644, F&D 49]

Gramineae

Agropyron caninum (L.) Beauv., bearded wheat-grass. Occasional to abundant, mountain meadows, ABAM zone. [F&D 228]

Agrostis alba L. var. *palustris* (Huds.) Pers., creeping bent-grass. Occasional to common, disturbed roadsides, both zones. [F 770, D 10]

Agrostis diegoensis Vasey, leafy bent-grass. Collected near entrance (lower Lookout Creek), TSHE zone. [F 627]

[2/] At the recommendation of F. J. Hermann we are using *Carex ormantha* (Fern.) Mack. instead of *C. muricata* L. which C. L. Hitchcock uses for this taxon.

Agrostis exarata Trin., western bent-grass. Occasional, mountain meadows and wet roadsides, ABAM zone. [F 774, F&D 221]

Agrostis scabra Willd., rough bent-grass. Occasional, open forest and mountain meadows, ABAM zone. [F 760, F&D 197]

Agrostis tenuis Sibth., colonial bent-grass. Introduced, occasional on disturbed sites, both zones. [F 442, F 788]

Agrostis thurberiana A. S. Hitchc., Thurber's bent-grass. Collected at bog on Lookout Mountain, ABAM zone. [F 736]

Aira caryophyllea L., silvery hair-grass. Occasional, rock outcrops along creeks, TSHE zone. [F 364]

Avena sativa L., common cultivated oat. Introduced as bait, rare, TSHE zone. [F 438a, F 762, F&D 227]

Bromus carinatus Hook. & Arn., California brome-grass. Occasional to common, clearcuts, forest openings, and mountain meadows, ABAM zone.

Bromus ciliatus L., fringed brome-grass. Collected on clearcut area, TSHE zone. [D 9]

Bromus orcuttianus Vasey, Orcutt's brome-grass. Occasional, in open forest, ABAM zone. [F 338]

Bromus sterilis L., sterile brome-grass. Collected in clearing near entrance (lower Lookout Creek), TSHE zone. [F 628, F&D 162]

Bromus vulgaris (Hook.) Shear, narrow-flowered brome-grass. Common, dry forests and clearcuts, TSHE zone. [F&D 57, F&D 183, F&D 184, D 35]

Calamagrostis canadensis (Michx.) Beauv., blue joint. Common, margins of temporary ponds and bogs, both zones. [F 638, F&D 111]

Calamagrostis inexpansa Gray, narrow-spiked reed-grass. Collected at bog on Lookout Mountain, ABAM zone. [F 740]

Deschampsia caespitosa (L.) Beauv., tufted hair-grass. Collected at bog on Lookout Mountain, ABAM zone. [F 737, F&D 109]

Deschampsia elongata (Hook.) Munro ex Benth., slender hair-grass. Occasional, disturbed areas, TSHE zone. [F 357, F 631]

Elymus glaucus Buckl., western rye-grass. Occasional, open woods and mountain meadows, ABAM zone. [F&D 199, F&D 205]

Elymus glaucus x *Sitanion hystrix*, Hansen's squirrel-tail. Collected on summit of Carpenter Mountain, ABAM zone. [F 786]

Festuca arundinacea Schreb., tall meadow fescue. Introduced, common in disturbed areas such as roadsides, both zones. [F 356, F 430, F 444]

Festuca bromoides L., six-weeks fescue. Introduced, collected on skid roads in clearcuts, TSHE zone. [F 359]

Festuca megalura Nutt., western six-weeks fescue. Occasional, dry rock outcrops, TSHE zone. [F 366]

Festuca occidentalis Hook., western fescue. Widespread and sometimes common, in dry, open woods, and less often on clearcuts, both zones. [F 358, F 791, F792a, F&D 56, F&D 99, F&D 181, F&D 182, F&D 203, D 8]

Festuca ovina L., sheep fescue. Occasional, mountain meadows, ABAM zone. [F&D 16]

Festuca pratensis Huds., meadow fescue. Introduced, collected on clearcut area, TSHE zone. [D 34]

Festuca rubra L., red fescue. Widespread, and sometimes common, especially on roadsides and disturbed sites, ABAM zone. [F 431, F 439, F 761, F 793, F&D 225]

Festuca subulata Trin. in Bong., nodding fescue. Collected along disturbed streamside, TSHE zone. [F 441]

Glyceria elata (Nash) M. E. Jones, tall manna-grass. Common, swamps and boggy areas, both zones. [F 546, F 647, F 755, M 14]

Hierochloe occidentalis Buckley, western vanilla grass. Rare, dry forest, TSHE zone. [F&D 230]

Holcus lanatus L., velvet grass. Introduced, widespread along roadsides and clearcuts, both zones. [F 548]

Koeleria cristata (L.) Pers., June grass or Koeler's-grass. Occasional, forest openings and mountain meadows, ABAM zone. [F&D 223]

Lolium perenne L., English rye-grass. Introduced, widespread (used in roadbank seedings) and sometimes common, both zones. [F 629]

Melica aristata Thurb. ex Boland., awned melic. Collected in open forest, ABAM zone. [F&D 132]

Melica harfordii Boland., Harford's melic. Occasional to common, disturbed areas such as clearcuts, TSHE zone. [F&D 147, F&D 185, D 28, D 65]

Melica smithii (Porter) Vasey, Smith's melic. Collected in open forest, ABAM zone. [F&D 204]

Melica subulata (Griseb.) Scribn., Alaska onion-grass. Occasional to common in forests, forest opening, and clearcut areas, TSHE zone. [F 365, F 535, F&D 24]

Muhlenbergia filiformis (Thurb.) Rydb., slender muhlenbergia. Collected in bog on Lookout Mountain, ABAM zone. [F 749]

Panicum capillare L., old-witch grass. Collected in clearing near entrance (lower Lookout Creek), TSHE zone. [D 71]

Pleuropogon refractus (Gray) Benth. in Vasey, nodding pleuropogon. Occasional to common, swamps and boggy areas, both zones. [F 739, F&D 50]

Poa gracillima Vasey, Pacific bluegrass. Occasional rock outcrops, both zones. [F 790, F&D 174]

Poa incurva Scribn. & Williams, subalpine Sandberg's bluegrass. Occasional, mountain meadows, ABAM zone. [F 719]

Poa scabrella (Thurb.) Benth. ex Vasey, malpais bluegrass. Occasional, mountain meadows, ABAM zone. [F&D 226]

Puccinellia pauciflora (Presl) Munz, few-flowered alkali grass. Swampy areas, TSHE zone. [F&D 62, M 8]

Sitanion hystrix (Nutt.) J. G. Smith, bottle-brush squirrel-tail. Collected on summit of Carpenter Mountain, ABAM zone. [F&D 222]

Stipa occidentalis Thurb. ex Wats., western stipa or needlegrass. Collected on summit of Carpenter Mountain, ABAM zone. [F 789]

Stipa occidentalis Thurb. ex Wats. var. *minor* (Vasey) C. L. Hitchc., subalpine stipa or needlegrass. Occasional to common, mountain meadows, ABAM zone. [F&D 121, F&D 198]

Trisetum cernuum Trin., nodding trisetum. Common, open woods, ABAM zone. [F 340, F&D 131]

Trisetum spicatum (L.) Richter, downy oat-grass. Collected on summit of Carpenter Mountain, ABAM zone. [F 792]

Triticum aestivum L., wheat. Introduced as bait, rare, TSHE zone. [D 67]

Sparganiaceae

Sparganium simplex Huds., simple-stemmed bur-reed. Collected in swampy area, TSHE zone. [M 11]

Typhaceae

Typha latifolia L., broad-leaved cattail. Common, wet areas, especially along roadsides and in clearcuts, both zones.

Araceae

Lysichitum americanum Hultén & St. John, yellow skunk-cabbage. Common, swampy habitats, both zones.

Liliaceae

Brodiaea congesta Smith, field brodiaea. Occasional, rocky outcrops, TSHE zone. [F&D 76]

Calochortus subalpinus Piper, Cascade mariposa lily. Common, mountain meadows, ABAM zone. [F 409]

Clintonia uniflora (Schult.) Kunth, one-flowered clintonia or queen-cup bead-lily. Common, forests of upper TSHE and ABAM zones, but extending to lower elevations along Lookout Creek.

Disporum hookeri (Torr.) Nicholson var. *oreganum* (Wats.) Q. Jones, Hooker's fairy bells. Common, moist forests and streamsides, TSHE zone. [D 11]

Erythronium grandiflorum Pursh, yellow adder's tongue or fawn lily. Common, rock outcrops and meadow areas, ABAM zone. [F 97, F&D 94]

Lilium columbianum Hanson in Baker, Columbia or tiger lily. Occasional, clearcuts and second growth forest, both zones. [F&D 75]

Lilium washingtonianum Kell. var. *purpurascens* Stearn, Washington's lily. Occasional, forest or clearcut areas, both zones. [D 48]

Maianthemum dilatatum (Wood) Nels. & Macbr., false lily-of-the-valley. Rare, dense forest along lower Mack Creek, TSHE zone. [F&D 188]

Smilacina racemosa (L.) Desf., false Solomon's seal. Widespread, occasional, forest and clearcut areas, both zones. [F&D 65]

Smilacina stellata (L.) Desf., few-flowered false Solomon's seal. Widespread, occasional to common, moist forests, both zones.

Stenanthium occidentale Gray, western stenanthium. Rare, collected in seepage area, TSHE zone. [F&D 167]

Streptopus amplexifolius (L.) DC. in Lam. & DC., larger twisted-stalk. Occasional, moist to wet forests, TSHE zone. [F&D 142]

Streptopus roseus Michx. var. *curvipes* (Vail) Fassett, smaller twisted-stalk. Occasional in moist, shady forest, Frissel Mountain, ABAM zone.

Trillium ovatum Pursh, western trillium or wake-robin. Widespread, occasional to common, forests and clearcut areas, both zones. [F 11]

Veratrum viride Ait., green false hellebore. Occasional, mountain meadows, ABAM zone.

Xerophyllum tenax (Pursh) Nutt., Indian basket-grass or bear-grass. Widespread, common to abundant, forests, both zones. [F&D 141]

Zigadenus venenosus Wats. var. *gramineus* (Rydb.) Walsh ex Peck, poison or death camas. Common, rock outcrops and mountain meadows, ABAM zone. [F 410, F 703]

Iridaceae

Iris chrysophylla Howell, slender-tubed iris. Occasional, forests and clearcuts, both zones. [F 49, D 12]

Iris tenax Dougl. ex Lindl., Oregon iris. Occasional to common, dry forests and clearcuts, TSHE zone. [F 540]

Orchidaceae

Calypso bulbosa (L.) Oakes in Thompson, calypso (fairy slipper). Rare to abundant, dense forests, TSHE zone. [F 666]

Corallorhiza maculata Raf., spotted coral-root. Occasional, dense forests, both zones. [F&D 47]

Corallorhiza mertensiana Bong., Merten's or western coral-root. Occasional to common, dense forests, both zones.

Eburophyton austiniae (Gray) Heller, ghost orchid. Widespread, but rare, dense forests, both zones.

Goodyera oblongifolia Raf., rattlesnake plantain. Common, dense forests, both zones.

Habenaria dilatata (Pursh) Hook., collected in seepage area, TSHE zone. [F&D 165]

Habenaria saccata Greene, slender bog orchid. Collected in bog on Lookout Mountain, ABAM zone. [F 106]

Habenaria unalascensis (Spreng.) Wats., occasional, dry forests, TSHE zone. [D 41]

Listera caurina Piper, western twayblade. Occasional to common, dense forests, both zones. [F&D 27, F&D 187]

Listera cordata (L.) R. Br. in Ait., heart-leaved twayblade. Occasional, forests, TSHE zone. [F 187a, F&D 143]

Salicaceae

Populus trichocarpa T. & G. ex Hook., black cottonwood. Common, along creeks and on cutover areas, especially moist habitats, TSHE zone.

Salix geyeriana Anderss., collected around bog on Lookout Mountain, ABAM zone. [F 753]

Salix lasiandra Benth., red willow. Common, moist areas on clearcuts and along roads, both zones. [F 763, F&D 33, F&D 64]

Salix scouleriana Barratt in Hook., Scouler willow. Common, clearcut areas, TSHE zone. [F 13, F 360]

Salix sitchensis Sanson in Bong., Sitka willow. Common, swamps, boggy areas, and moist sites on clearcuts and along roadsides, both zones. [F 361, F 542, F 752, F 766, F&D 60]

Betulaceae

Alnus rubra Bong., red alder. Common, moist to wet areas of clearcuts and along roadsides and in swampy areas, TSHE zone. [F 63]

Alnus sinuata (Regel) Rydb., Sitka alder. Abundant in snowslide communities, ABAM zone.

Corylus cornuta Marsh. var. *californica* (DC.) Sharp, California hazel. Widespread, most common dry forests and clearcuts, TSHE zone, but distributed to summit Carpenter Mountain, ABAM zone.

Fagaceae

Castanopsis chrysophylla (Dougl.) A. DC., golden chinkapin. Widespread, common, dry forests and clearcuts, TSHE zone, typically attaining tree size on dry ridges. [F 58]

Quercus garryana Dougl. ex Hook., Oregon white oak. Rare, dry rock outcrops, both zones (collected near summit Lookout Mountain). [F 725]

Loranthaceae

Arceuthobium campylopodum Engelm. forma *tsugensis* (Rosend.) Gill, yellow leafless mistletoe or dwarf mistletoe. Occasional to common, western and mountain hemlock stands, and sometimes in associated Pacific silver firs, both zones.

Santalaceae

Comandra umbellata (L.) Nutt. var. *californica.* (Eastw.) C. L. Hitchc., bastard toad-flax. Occasional to common, mountain meadows, clearcuts, and forest openings, ABAM zone. [F 414, F 726, F&D 213]

Aristolochiaceae

Asarum caudatum Lindl., western wild ginger. Occasional, generally in moist forest, both zones.

Polygonaceae

Eriogonum compositum Dougl. ex Benth. var. *compositum,* heart-leaved eriogonum. Occasional, rock outcrops and dry meadows, ABAM zone. [F&D 90, F&D 195]

Eriogonum umbellatum Torr. var. *umbellatum,* sulphur-flowered eriogonum. Occasional, rock outcrops and dry meadows, ABAM zone.

Polygonum douglasii Greene, Douglas' knotweed. Occasional, rock outcrops and dry meadows, ABAM zone. [F 656, D 72]

Polygonum minimum Wats., leafy knotweed. Occasional, rock outcrops and dry meadows, ABAM zone. [F 657]

Polygonum phytolaccaefolium Meisn. ex Small, jimson knotweed. Common, mountain meadows and boggy areas, ABAM zone. [F 653, F 741, F 779]

Rumex acetosella L., red sorrel. Introduced, common, disturbed areas and mountain meadows, both zones. [F 419]

Rumex crispus L., curly-leaved dock. Introduced, collected along roadsides, TSHE zone. [F&D 171]

Rumex crispus L., curly-leaved dock. Introduced, collected along roadsides, TSHE zone. [F&D 171]

Rumex obtusifolius L., broad-leaved dock. Rare, collected along roadsides, TSHE zone. [F&D 55]

Portulacaceae

Claytonia lanceolata Pursh, lance-leaved spring beauty. Occasional in mountain meadows, early spring, ABAM zone.

Lewisia triphylla (Wats.) Robins., three-leaved lewisia. Common, rock outcrops, ABAM zone. [F 709, F&D 18]

Montia cordifolia (Wats.) Pax & K. Hoffm. in E. & P., broad-leaved montia. Occasional, wet areas, both zones. [F 438]

Montia parvifolia (Moc.) Greene var. *parvifolia*, streambank spring beauty. Occasional to common, streamsides, TSHE zone. [F 363, F 794]

Montia perfoliata (Donn) Howell, miner's lettuce. Widespread, occasional to common, moist forest and clearcut areas, both zones. [F 705, D 16]

Montia sibirica (L.) Howell, western spring beauty. Widespread, common in moist forest and cutover areas, both zones. [F 105, F 437, F 706, D 17]

Caryophyllaceae

Arenaria capillaris Poir. var. *americana* (Maguire) Davis, American sandwort. Occasional on Lithosols on ridges, collected in cutover area, ABAM zone. [F 416]

Arenaria macrophylla Hook., large-leaved sandwort. Widespread, occasional to common, rock outcrops, mountain meadows, and clearcuts, both zones. [F 536, F 708, F&D 149, D 13]

Cerastium arvense L., field chickweed. Common, mountain meadows, ABAM zone. [F 713, F&D 215]

Silene douglasii Hook., Douglas' campion or pink. Occasional on Lithosols or exposed south-facing outcrops, ABAM zone. [H 482-3]

Silene menziesii Hook., Menzie's campion or pink. Rare, rock outcrops, both zones. [F&D 91]

Stellaria calycantha (Ledeb.) Bong. (= *S. borealis*), northern starwort. Collected in boggy area on Carpenter Mountain, ABAM zone. [F 775]

Stellaria crispa Cham. & Schlecht., crisped starwort. Collected along roadside, ABAM zone. [F 764]

Ranunculaceae

Actaea rubra (Ait.) Willd., western baneberry. Widespread, occasional, wet forests and cutover areas, both zones. [F&D 72]

Anemone deltoidea Hook., western white anemone. Common, dense forests, primarily ABAM zone. [F&D 23]

Anemone lyallii Britt., little mountain anemone. Occasional, forests and cutover areas, TSHE zone. [F 10, F 665, D 22]

Anemone oregana Gray, Oregon anemone. Occasional, forests and cutover areas, ABAM zone.

Aquilegia formosa Fisch. in DC., western columbine. Occasional, mountain meadows and forest openings, ABAM zone. [M 3]

Coptis laciniata Gray, western gold-thread. Common, dense forests, TSHE and lower ABAM zones. [F 345]

Delphinium menziesii DC. var. *pyramidale* (Ewan) C. L. Hitchc. (= *D. nuttallianum*), Menzie's larkspur. Common, rock outcrops and mountain meadows, ABAM zone. [F 423, F 715]

Delphinium trolliifolium Gray, poison larkspur. Single plant observed in moist clearcut, Frissell Mountain, ABAM zone.

Ranunculus occidentalis Nutt. in T. & G., western buttercup. Rare, observed in clearcut, Lookout Mountain, ABAM zone.

Ranunculus uncinatus D. Don in G. Don var. *parviflorus* (Torr.) Benson, little buttercup. Along streams and clearcut areas, both zones. [F&D 36]

Thalictrum occidentale Gray, western meadow-rue. Occasional to common, streamside areas, dense forests, and clearcuts, TSHE zone. [F 106]

Berberidaceae

Achlys triphylla (Smith) DC., vanilla-leaf. Common to abundant, forest and cutover areas, both zones. [F 100]

Berberis aquifolium Pursh, Oregon grape. Rare, except occasional along rocky ridges, ABAM zone. [F&D 30]

Berberis nervosa Pursh, long-leaved Oregon grape. Widespread, common to abundant, forests and cutover areas, both zones.

Vancouveria hexandra (Hook.) Morr. & Dec., inside-out flower. Common, moist forests and cutover areas, both zones.

Fumariaceae

Dicentra formosa (Andr.) Walpers, western bleeding-heart. Occasional to common, moist habitats in forests, cutover areas, and in Sitka alder communities, both zones. [F 79, F&D 70]

Dicentra uniflora Kell., one-flowered dicentra. Observed on Carpenter Mountain, ABAM zone.

Cruciferae

Arabis hirsuta (L.) Scop. var. *glabrata* T. & G., hairy rock cress. Collected on rock outcrop, TSHE zone. [F&D 97]

Arabis holboellii Hornem. var. *retrofracta* (Grah.) Rydb., Holboell's rock cress. Common, mountain meadows and rock outcrops, ABAM zone. [F&D 13]

Cardamine breweri Wats., Brewer's bitter cress. Collected in swampy area, TSHE zone. [F&D 180]

Cardamine occidentalis (Wats.) Howell, western bitter cress. Collected from stream in cutover area, upper TSHE zone. [F 530]

Cardamine oligosperma Nutt. in T. & G., little western bitter cress. Occasional, wet portions of cutover areas, TSHE zone. [F 661, F 668, M 9]

Cardamine oligosperma Nutt. in T. & G. var. *kamtschatica* (Regel) Detl., little western bitter cress. Occasional, portions of temporary ponds, TSHE zone. [F 636]

Cardamine pulcherrima (Robins.) Greene var. *tenella* (Pursh) C. L. Hitchc., slender dentaria. Occasional, second-growth forest and cutover areas, TSHE zone. [D 20]

Erysimum asperum (Nutt.) DC., rough wallflower. Common to abundant, mountain meadows, ABAM zone. [F 418, F 714]

Rorippa curvisiliqua (Hook.) Bessey ex Britt., western yellow cress. Occasional, portions of temporary ponds, TSHE zone. [F 635]

Crassulaceae

Sedum oreganum Nutt. in T. & G., Oregon stonecrop. Occasional on shaded rock outcrops, Frissell Mountain, ABAM zone.

Sedum oregonense (Wats.) Peck, creamy stonecrop. Rock outcrops, ABAM zone. [F&D 191]

Sedum spathulifolium Hook., broad-leaved stonecrop. Collected from rock outcrops along Lookout Creek, TSHE zone. [F&D 85]

Sedum stenopetalum Pursh, narrow-petaled stonecrop. Occasional on Lithosols and rock outcrops, Frissell Mountain, ABAM zone. [H 482-4]

Saxifragaceae

Boykinia elata (Nutt.) Greene, slender boykinia. Occasional along Lookout Creek and on Carpenter Mountain, both zones. [F 145, F&D 82]

Boykinia major Gray var. *major*, large-flowered boykinia. Collected in bog on Lookout Mountain, ABAM zone. [F 734, F&D 104]

Heuchera micrantha Dougl. ex Lindl., small-flowered heuchera. Widespread, rock outcrops, both zones. [F 400, F&D 78]

Lithophragma parviflora (Hook.) Nutt. ex T. & G., small-flowered fringecup. Forest openings and mountain meadows, ABAM zone. [F 712]

Mitella breweri Gray, feathery mitrewort. Occasional, moist woods, ABAM zone. [F 551]

Mitella ovalis Greene, oval-leaved mitrewort. Occasional, moist forest and cutover areas, TSHE zone. [F 531, F 667]

Mitella trifida Grah., three-toothed mitrewort. Occasional, moist forest, ABAM zone. [F&D 17]

Saxifraga ferruginea Grah. var. *macounii* Engl. & Irmsch., rusty saxifrage. Occasional to common, forest openings, rock outcrops, and occasionally disturbed roadsides, ABAM zone. [F 765, F&D 20]

Saxifraga integrifolia Hook., northwestern saxifrage. Occasional on vernal-wet rock outcrops, Carpenter Mountain, ABAM zone.

Saxifraga mertensiana Bong., Merten's saxifrage. Rock outcrops along Lookout Creek, TSHE zone. [F 362]

Saxifraga occidentalis Wats. var. *rufidula* (Small) C. L. Hitchc., western saxifrage. Common, rock outcrops, both zones. [F&D 4, F&D 93]

Saxifraga oregana Howell, Oregon saxifrage. Occasional in forest openings and on clearcuts, ABAM zone. [F 702]

Tellima grandiflora (Pursh) Dougl. in Lindl., large fringe-cup. Occasional, moist woods and clearcuts, both zones.

Tiarella laciniata Hook., lance-leaved coolwort. Rare, observed in forest along upper Lookout Creek, TSHE zone.

Tiarella trifoliata L., three-leaved coolwort. Occasional, moist forests, TSHE zone.

Tiarella unifoliata Hook., western coolwort or foam flower. Common to abundant, forests and clearcut areas, especially on moister sites, both zones. [F&D 69]

Tolmiea menziesii (Pursh) T. & G., youth-on-age. Common along creeks and occasional in wet habitats, both zones. [F 103, F&D 84]

Grossulariaceae

Ribes binominatum Hel., Siskiyou gooseberry. Common in clearcuts and beneath *Abies grandis* in meadows on Lookout and Frissell Mountains, ABAM zone. [H 217-1]

Ribes bracteosum Dougl. ex Hook., stink currant. Rare to occasional, wet areas in forests or on cutovers, both zones.

Ribes lacustre (Pers.) Poir. in Lam., occasional to common, moist forests and cutovers, both zones. [F 69, F 541]

Ribes lobbii Gray, pioneer gooseberry. Collected in small clearcuts, upper TSHE zone. [F 53]

Ribes sanguineum Pursh, red-flowering currant. Rare in forests, common on clearcut areas, both zones. [F 78, D 19]

Ribes viscosissimum Pursh var. *hallii* Jancz., sticky currant. Occasional to common, forests and cutover areas, ABAM zone. [F 96]

Hydrangeaceae

Whipplea modesta Torr., modest whipplea. Common to abundant, cutover areas and dry forests, TSHE zone. [F&D 101]

Rosaceae

Amelanchier alnifolia Nutt. var. *humptulipensis* (G. N. Jones) C. L. Hitchc., western serviceberry. Occasional, cutover areas, TSHE zone. [D 31]

Amelanchier alnifolia Nutt. var. *semiintegrifolia* (Hook.) C. L. Hitchc., western serviceberry. Occasional to common, old burns and forest openings, ABAM zone.

Aruncus sylvester Kostel in Ind., goat's-beard. Occasional to common on wet roadsides, both zones. [M 4]

Fragaria vesca L. var. *bracteata* (Heller) Davis, western wood strawberry. Rock outcrops, cutovers, and mountain meadows, both zones. [F 533, F 662]

Fragaria virginiana Duchesne var. *platypetala* (Rydb.) Hall, broad-petaled strawberry. Collected in mountain meadow, ABAM zone. [F 425]

Geum macrophyllum Willd. var. *macrophyllum*, large-leaved avens. Occasional in wet meadows, ABAM zone. [F 742]

Holodiscus discolor (Pursh) Maxim., ocean-spray. Occasional to common in dry forest and cutover areas, TSHE zone, but extending to ABAM zone on rock outcrops and in very dry forests.

Osmaronia cerasiformis (T. & G.) Greene, Indian plum. Occasional, cutover areas, TSHE zone. [F 343]

Potentilla glandulosa Lindl., sticky cinquefoil. Occasional, mountain meadows and rock outcrops, ABAM zone. [F&D 218]

Potentilla gracilis Dougl. ex Hook. var. *gracilis*, slender cinquefoil. Occasional, mountain meadows, ABAM zone. [F&D 127]

Potentilla gracilis Dougl. ex Hook. var. *permollis* (Rydb.) C. L. Hitchc., occasional, mountain meadows, ABAM zone. [F&D 127]

Prunus emarginata (Dougl.) Walpers, bittercherry. Common, cutover areas, both zones. [F 543]

Rosa gymnocarpa Nutt. in T. & G., little wildrose. Occasional, forests and cutover areas, both zones. [F 427]

Rubus lasiococcus Gray, dwarf bramble. Common, forests, ABAM zone.

Rubus leucodermis Dougl. ex T. & G., western blackcap. Occasional to common, cutover areas, TSHE zone.

Rubus nivalis Dougl. ex Hook., snow bramble. Occasional, cutover areas and forests, upper TSHE and lower ABAM zones.

Rubus parviflorus Nutt., thimbleberry. Occasional to common, cutover areas and mountain meadows, both zones. [D 39]

Rubus procerus Muell. in Boulay, Himalaya berry. Introduced, observed on roadsides and cutover areas, TSHE zone.

Rubus spectabilis Pursh, salmonberry. Occasional, wet portions of cutover areas or rarely forests, both zones.

Rubus ursinus Cham. & Schlecht., western dewberry or trailing blackberry. Widespread, common to abundant, forests and cutover areas, both zones.

Sorbus sitchensis Roemer, western mountain ash. Occasional, forest openings, ABAM zone.

Spiraea douglasii Hook., western spiraea. Occasional to common, swamps and temporary ponds, both zones. [F&D 61]

Leguminosae

Cytisus scoparius (L.) Link, Scotch broom. Introduced, roadsides and cutover areas, both zones. [F&D 31]

Lathyrus holochlorus (Piper) C. L. Hitchc., thin-leaved pea. Rare, in clearcut on Lookout Mountain, ABAM zone.

Lathyrus nevadensis Wats. ssp. *lanceolatus* (Howell) C. L. Hitchc., var. *pilosellus* (Peck) C. L. Hitchc., Sierra Nevada pea. Widespread, occasional to common, cutover areas, both zones, and in boggy areas, ABAM zone. [F 424, F 745, F&D 54]

Lathyrus nevadensis Wats. ssp. *nevadensis*, Sierra Nevada pea. Occasional, mountain meadows, ABAM zone. [F 710]

Lathyrus polyphyllus Nutt. ex T. & G., leafy pea. Occasional, cutover areas and dry forests, TSHE zone. [D 21]

Lotus corniculatus L., bird's foot trefoil. Introduced, collected on cutover area, TSHE zone. [M 21]

Lotus crassifolius (Benth.) Greene, thick-leaved lotus. Occasional to common, cutover areas, upper TSHE and lower ABAM zones. [F&D 29]

Lotus micranthus Benth., small-flowered lotus. Occasional, collected on cutover area, TSHE zone. [D 26]

Lotus nevadensis (Wats.) Greene var. *douglasii* (Greene) Ottley, Douglas' lotus. Occasional to common, rock outcrops, both zones. [F&D 53, F&D 98]

Lotus purshianus (Benth.) Clements & Clements, Pursh's lotus. Occasional to abundant, roadsides, cutover areas, and mountain meadows, both zones. [F 545, F&D 35, F&D 212]

Lupinus latifolius Agardh, broadleaved lupine. Common, cutover areas and roadsides, both zones.

Lupinus laxiflorus Dougl. ex Lindl. var. *laxiflorus*, spurred lupine. Forest openings and mountain meadows, ABAM zone. [F&D 9, F&D 175]

Melilotus alba Desr. in Lam., white sweet-clover. Introduced, collected along roadside, TSHE zone. [M 18]

Trifolium dubium Sibth., least hop clover. Introduced, collected along roadside, TSHE zone. [F&D 87]

Trifolium pratense L., red clover. Introduced, occasional, collected along roadside, TSHE zone. [F&D 32]

Trifolium repens L., white clover. Introduced, occasional to common, cutover areas and roadsides, both zones. [F 444a]

Trifolium wormskjoldii Lehm., spring-bank clover. Collected in clearing near entrance (lower Lookout Creek), TSHE zone. [F&D 79]

Vicia americana Muhl. ex Willd. var. *truncata* (Nutt.) Brew., American vetch. Common, mountain meadows and boggy areas, ABAM zone. [F 746, F&D 115, F&D 208]

Vicia americana Muhl. ex Willd. var. *villosa* (Kell.) Hermann, California vetch. Occasional, cutover areas, TSHE and lower ABAM zones. [F&D 43, D 18]

Geraniaceae

Geranium carolinianum L., Carolina geranium. Collected in cutover area, TSHE zone. [D 27]

Geranium dissectum L., cut-leaved geranium. Introduced, collected in cutover area, TSHE zone. [F 550]

Oxalidaceae

Oxalis oregana Nutt. ex T. & G., Oregon oxalis. Occasional to common, wet forests and cutover areas, TSHE and lower ABAM zones. [F 51]

Oxalis suksdorfii Trel., western yellow oxalis. Occasional, disturbed areas, both zones. [F&D 45]

Callitrichaceae

Callitriche heterophylla Pursh ex Darby, varied-leaf water starwort. Occasional, temporary ponds, TSHE zone. [M 7]

Anacardiaceae

Rhus diversiloba T. & G., poison oak. Occasional, dry forest and rock outcrops, TSHE zone.

Celastraceae

Pachistima myrsinites (Pursh) Raf., Oregon boxwood. Occasional to common, forests, cutover areas, and rock outcrops, upper TSHE and ABAM zones.

Aceraceae

Acer circinatum Pursh, vine maple. Widespread, common in forest and cutover areas, and abundant on some rock outcrops and talus, both zones. [F 77]

Acer glabrum Torr. var. *douglasii* (Hook.) Dippel, Douglas maple. Occasional, open forest on rocky ridge tops and around Sitka alder communities, both zones. [F 552]

Acer macrophyllum Pursh, bigleaf maple. Occasional in forest and common on cutover areas, TSHE zone, but abundant along creeks and extending as high as 1,350-meter elevation. [F 669]

Rhamnaceae

Ceanothus integerrimus H. & A., deerbrush. Occasional, dry cutover areas and roadsides, TSHE zone. [F&D 73]

Ceanothus sanguineus Pursh, buckbrush or redstem. Common, clearcuts and roadsides, TSHE zone.

Ceanothus velutinus Dougl. ex Hook. var. *laevigatus* (Hook.) T. & G., varnishleaf ceanothus. Common, dryer portions of cutover areas, lower TSHE zone.

Ceanothus velutinus Dougl. ex Hook. var. *velutinus*, snowbrush ceanothus. Common, old burns and cutover areas, upper TSHE and ABAM zones.

Rhamnus purshiana DC., cascara. Rare in forests and occasional on cutover areas, TSHE zone.

Hypericaceae

Hypericum anagalloides C. & S., bog St. John's-wort. Common, boggy areas, ABAM zone. [F 727, F&D 108]

Hypericum perforatum L., common St. John's-wort. Introduced, rare to occasional, roadsides and cutover areas, TSHE zone, and sometimes abundant in meadows of ABAM zone. [D 36]

Violaceae

Viola glabella Nutt. in T. & G., smooth woodland violet. Common, second-growth forests, in ABAM zone.

Viola nuttallii Pursh var. *bakeri* (Greene) C. L. Hitchc., Baker's violet. Occasional, dry meadow areas, ABAM zone. [F 415]

Viola orbiculata Geyer ex Hook., round-leaved violet. Occasional, forests and overcut areas, ABAM zone.

Viola palustris L., marsh violet. Collected in swampy area, TSHE zone. [F&D 58]

Viola sempervirens Greene, evergreen violet. Common to abundant, forests and cutover areas, TSHE and lower ABAM zones. [F 9]

Onagraceae

Circaea alpina L., small enchanter's nightshade. Common in Sitka alder communities and in disturbed microsites in forests, both zones. [F&D 135]

Epilobium alpinum L. var. *alpinum*, alpine willow-herb. Wet portions of cutover areas and bogs, ABAM zone. [F 435, F 731]

Epilobium alpinum L. var. *nutans* (Hornem.) Hook., Hornemann's willow-herb. Occasional on wet sites, Frissell and Lookout Mountains, ABAM zone.

Epilobium angustifolium L., fire-weed. Common to abundant, cutover areas, and rarely, open forests, both zones.

Epilobium glandulosum Lehm., glandular willow-herb. Occasional, wet areas, ABAM zone. [F&D 107]

Epilobium luteum Pursh, yellow-flowered willow-herb. Collected along wet roadsides, ABAM zone. [F 762a]

Epilobium minutum Lindl. ex Hook., small-flowered willow-herb. Widespread, occasional to common, cutover areas and mountain meadows, both zones. [D 4, F&D 211]

Epilobium paniculatum Nutt. ex T. & G., tall annual willow-herb. Occasional to common, cutover areas, both zones.

Epilobium watsonii Barbey in Brew. & Wats., Pacific willow-herb. Occasional, cutover areas and mountain meadows, both zones.

Epilobium watsonii Barbey in Brew. & Wats. var. *occidentale* (Trel.) C. L. Hitchc., common western willow-herb. Occasional to common, cutover areas, both zones. [F 109]

Gayophytum humile Juss., dwarf gayophytum. Occasional to common on Lithosols and dry meadows, ABAM zone. [F&D 3, H 218-4]

Gayophytum diffusum T. & G. ssp. *parviflorum* Lewis & Szweyk., spreading gayophytum. Common on dry open ridges, Frissell Mountain, ABAM zone. [H 484-4]

Araliaceae

Aralia californica Wats., western aralia, ginseng, elk clover. Occasional to common, streamsides and forests or cutovers, mainly in TSHE zone. [F 440]

Oplopanax horridum (J. E. Smith) Miq., devil's club. Occasional to common, streamsides, wet forests, and Sitka alder communities, both zones.

Umbelliferae

Angelica arguta Nutt. in T. & G., shining angelica. Occasional in mountain meadows and common in boggy areas, ABAM zone. [F 758, F&D 217]

Angelica genuflexa Nutt. in T. & G., kneeling angelica. Collected in bog on Lookout Mountain, ABAM zone. [F 640]

Cicuta douglasii (DC.) Coult. & Rose, western waterhemlock. Collected in bog on Lookout Mountain, ABAM zone. [F 641, F 751]

Daucus carota L., wild carrot, Queen Anne's lace. Introduced, collected on cutover area, TSHE zone. [D 49]

Heracleum lanatum Michx., cowparsnip. Occasional, wet habitats, including seeps and bogs in wet meadows, both zones.

Ligusticum grayi Coult. & Rose, Gray's lovage. Common, mountain meadows and forest openings, ABAM zone. [F 342, F 777, F&D 216]

Lomatium hallii (S. Wats.) Coult. & Rose, canyon desert parsley. Occasional, rock outcrops and cutover areas, TSHE zone. [F 534, F&D 144]

Lomatium martindalei Coult. & Rose, few-fruited desert parsley. Common, rock outcrops, both zones. [F 95, F 532, F 716]

Lomatium nudicaule (Pursh) Coult. & Rose, naked desert parsley or pestle parsnip. Collected near summit Lookout Mountain, ABAM zone. [F&D 189]

Lomatium utriculatum (Nutt.) Coult. & Rose, fine-leaved desert parsley. Observed on cutover area, TSHE zone.

Orogenia fusiformis S. Wats., mountain orogenia. Cutover areas and mountain meadows, ABAM zone. [F&D 150]

Osmorhiza chilensis H. & A., western sweet cicely. Occasional, moist forests and cutovers, TSHE zone. [F&D 83]

Osmorhiza purpurea (Coult. & Rose) Suksd., purplish sweet cicely. Occasional to common, open forests and mountain meadows, ABAM zone. [F 421]

Perideridia gairdneri (H. & A.) Mathias, western false caraway. Collected in moist cutover area, TSHE zone. [F&D 231]

Sanicula graveolens Poepp. ex DC., Sierra snake-root. Common, mountain meadows, ABAM zone. [F 717, F&D 220]

Cornaceae

Cornus canadensis L., bunchberry or dwarf dogwood. Occasional to common, forests and cutovers, upper TSHE and ABAM zones.

Cornus nuttallii Aud. ex T. & G., Pacific or flowering dogwood. Common, dry forests and cutover areas, TSHE zone. [F 59, F 670]

Garryaceae

Garrya fremontii Torr., bear bush. Observed on cutover area, TSHE zone.

Ericaceae

Allotropa virgata T. & G. ex Gray, sugar stick. Rare, dry forests, TSHE zone.

Arbutus menziesii Pursh, Pacific madrone. Occasional, cutover areas and dry forests, TSHE zone.

Arctostaphylos columbiana Piper in Piper & Beattie, bristly or hairy manzanita. Occasional, cutover areas, TSHE zone. [F 344]

Arctostaphylos nevadensis Gray, pine-mat manzanita. Occasional to common, rock outcrops, both zones. [F&D 14, D 32]

Chimaphila menziesii (R. Br.) Spreng., little prince's pine. Occasional, dense forests, both zones.

Chimaphila umbellata (L.) Bart. var. *occidentalis* (Rydb.) Blake, western prince's pine. Occasional to common, forests and cutover areas, both zones. [F 99]

Gaultheria ovatifolia Gray, slender gaultheria. Occasional, dense forests, upper TSHE and lower ABAM zones. [F&D 28, F&D 159]

Gaultheria shallon Pursh, salal. Occasional to abundant, forests and cutover areas, TSHE zone.

Hypopitys monotropa Crantz, broad-leaved pinesap. Occasional, dense forests, both zones.

Monotropa uniflora L., Indian pipe. Occasional, dense forests, both zones. [M 16]

Pterospora andromedea Nutt., pine drops. Rare, forests, TSHE zone.

Pyrola aphylla Smith in Rees, leafless pyrola. Occasional, dense forests, both zones.

Pyrola asarifolia Michx., large pyrola. Occasional to common, forests and cutover areas, TSHE and lower ABAM zones. [F 748]

Pyrola dentata Smith in Rees, toothed pyrola. Rare, collected in cutover areas, TSHE zone. [F&D 156]

Pyrola picta Smith in Rees, white-veined pyrola. Occasional to common, mainly dense forests, TSHE and lower ABAM zones.

Pyrola secunda L. var. *secunda,* one-sided wintergreen. Occasional to common, upper TSHE and ABAM zones.

Pyrola virens Schweigg. in Schweigg. & Koerte, greenish pyrola. Rare, collected in cutover area, TSHE zone. [F&D 186]

Rhododendron macrophyllum G. Don, Pacific rhododendron. Common to abundant, forests and cutovers, both zones. [F&D 152]

Vaccinium alaskaense Howell, Alaska blueberry. Occasional, forests and cutover areas, upper TSHE and ABAM zones. [F 658, F 672]

Vaccinium membranaceum Dougl. ex Hook., thin-leaved huckleberry. Widespread, occasional in forests, TSHE zone, common to abundant in forests and cutovers, ABAM zone.

Vaccinium parvifolium Smith in Rees, red huckleberry. Common, forests and cutovers, TSHE and lower ABAM zones.

Primulaceae

Dodecatheon jeffreyi van Houtte, tall mountain shooting star. Collected in bog on Lookout Mountain, ABAM zone. [F 434]

Trientalis latifolia Hook., broad-leaved star-flower. Occasional to common, dry forests, and cutover areas, TSHE zone.

Apocynaceae

Apocynum androsaemifolium L., spreading dogbane. Occasional, dry forests and cutovers, TSHE zone. [F&D 100]

Convolvulaceae

Convolvulus nyctagineus Greene, night-blooming morning-glory. Occasional, disturbed areas, both zones. [F&D 154]

Polemoniaceae

Collomia heterophylla Hook., varied-leaved collomia. Common, cutover areas and roadsides, TSHE zone. [F 549, F 630]

Collomia linearis Nutt., narrow-leaved collomia. Rock outcrops and dry meadows, ABAM zone. [F&D 1]

Gilia capitata Sims, blue field gilia. Common, rock outcrops and mountain meadows, both zones. [F 552a, F&D 88, F&D 124, D 25]

Microsteris gracilis (Hook.) Greene var. *gracilis,* pink annual phlox. Common, rock outcrops and dry meadows, both zones. [F 538, F 707, F&D 172, F&D 201]

Navarretia divaricata (Torr.) Greene, short-stemmed navarretia. Common, mountain meadows and rock outcrops, ABAM zone. [F&D 194]

Phlox adsurgens Torr. ex Gray, woodland phlox. Occasional, collected on cutovers, TSHE zone. [D 24]

Phlox diffusa Benth. var. *longistylis* (Wherry) Peck, spreading phlox. Occasional, rock outcrops and dry meadows, ABAM zone. [F&D 7]

Polemonium carneum Gray, great polemonium. Occasional, cutover areas and forests, ABAM zone. [F 417]

Hydrophyllaceae

Hydrophyllum occidentale (Wats.) Gray, western waterleaf. Occasional to common, moist meadows and habitats, ABAM zone. [F 701]

Hydrophyllum tenuipes Heller, slender-stemmed waterleaf. Occasional to common, moist habitats, both zones. [F 671]

Nemophila parviflora Dougl. ex Benth. var. *parviflora,* small-flowered nemophila. Widespread, cutover areas, seeps, mountain meadows, and forests, both zones. [F&D 163, F&D 177, F&D 209, D 14]

Phacelia heterophylla Pursh, varied-leaved phacelia. Common, cutover areas and some mountain meadows, ABAM zone. [F&D 5]

Boraginaceae

Cryptantha intermedia (Gray) Greene, large-flowered cryptantha. Collected on cutover area, TSHE zone. [D 40]

Mertensia bella Piper, Oregon lungwort. Occasional, moist meadows and forests, ABAM zone. [F 550a, F 700]

Myosotis discolor Pers. in Murr., yellow-and-blue scorpion-grass. Introduced, collected on cutover area, TSHE zone. [D 29]

Labiatae

Prunella vulgaris L. var. *lanceolata* (Barton) Fern., heal-all. Common, cutover areas, both zones. [F 510, F&D 80]

Stachys cooleyae Heller, great hedge nettle. Occasional to common, wet portions of cutovers, bogs, and Sitka alder communities, both zones. [F 744, F&D 136, M 20]

Stachys palustris L. var. *pilosa* (Nutt.) Fern., swamp hedge nettle. Wet portions of cutover areas, both zones. [F 511, F&D 103, D 52]

Stachys rigida Nutt. ex Benth. in DC. var. *rigida,* ridge hedge nettle. Observed on Carpenter and Lookout Mountains, ABAM zone.

Scrophulariaceae

Castilleja hispida Benth. in Hook. var. *hispida,* harsh paintbrush. Occasional, variety of forest openings, both zones. [F&D 19, F&D 157, F&D 164]

Castilleja miniata Dougl. ex Hook., common paintbrush. Forest openings and mountain meadows, ABAM zone. [F&D 118]

Collinsia parviflora Lindl., small-flowered collinsia. Rock outcrops and mountain meadows, ABAM zone. [F&D 2]

Digitalis purpurea L., foxglove. Introduced, occasional, cutover areas, TSHE zone. [F&D 161]

Linaria vulgaris Hill, butter-and-eggs. Introduced, occasional, cutover areas, TSHE zone. [D 33]

Mimulus alsinoides Dougl. ex Benth., chickweed monkeyflower. Occasional, rock outcrops and cutover areas, both zones. [F 537, F 660, D 15]

Mimulus breweri (Greene) Rydb., Brewer's monkeyflower. Occasional, mountain meadows, ABAM zone. [F&D 210]

Mimulus guttatus DC., common monkeyflower. Common, along streams, in wet portions of clearcuts, and in boggy areas, both zones. [F 104, F 743, F&D 81, F&D 232]

Mimulus moschatus Dougl. in Lindl., musk monkeyflower. Occasional to common, wet meadows and wet portions of clearcut areas, upper TSHE and ABAM zones. [F 426, F&D 44]

Nothochelone nemorosa (Dougl.) Straw, woodland penstemon. Occasional in open forest, Carpenter and Frissell Mountains, ABAM zone.

Orthocarpus imbricatus Torr. ex Wats., mountain orthocarpus. Common, mountain meadows and cutover areas, ABAM zone. [F 420, F 759]

Pedicularis bracteosa Benth. in Hook. var. *flavida* (Pennell) Cronq., bracted pedicularis or lousewort. Common in wet meadows and boggy areas, ABAM zone.

Pedicularis contorta Benth. in Hook., coiled pedicularis or lousewort. Observed on Lookout Mountain, ABAM zone.

Pedicularis racemosa Dougl. ex Hook., leafy pedicularis or lousewort. Common, forests and cutover areas, both zones.

Penstemon cardwellii Howell, Cardwell's penstemon. Occasional, forest openings and cutovers, upper TSHE and ABAM zones. [M 5]

Penstemon procerus Dougl. ex R. Grah. var. *brachyanthus* (Pennell) Cronq., tall penstemon. Occasional to common, dry meadows, ABAM zone. [F&D 219]

Penstemon rupicola (Piper) Howell, rock penstemon. Occasional on exposed outcrops and rocky ridges, ABAM zone.

Penstemon serrulatus Menzies ex Smith in Rees, spreading penstemon. Common, cutover areas, forest openings, and meadows, both zones. [F 107, F&D 34, F&D 46, F&D 116, D 37]

Synthyris reniformis (Dougl.) Benth. in DC., round-leaved synthyris or snowqueen. Common, dry forests and cutover areas, TSHE zone. [F 663]

Verbascum thapsus L., mullein. Introduced, disturbed areas, both zones. [F&D 200]

Veronica americana Schwein. ex Benth. in DC., American speedwell. Common, swamps, streams, and wet portions of clearcut areas, both zones. [F&D 42, M 2, M 13]

Veronica arvensis L., corn speedwell. Introduced, collected in mountain meadow, ABAM zone. [F&D 207]

Veronica scutellata L., marsh speedwell. Swampy areas and temporary ponds, TSHE zone. [F 639, M 10, M 19]

Veronica serpyllifolia L., thyme-leaved speedwell. Observed on Carpenter Mountain, ABAM zone.

Orobanchaceae

Orobanche uniflora L. var. *minuta* (Suksd.) Beck, naked broom-rape. Occasional, typically on rock outcrops, both zones. [F 704, F&D 153]

Plantaginaceae

Plantago major L., common plantain. Introduced, occasional, disturbed areas, both zones. [F&D 86]

Rubiaceae

Galium aparine L. var. *echinospermum* (Wallr.) Farw., cleavers. Occasional, cutover areas, TSHE zone. [F&D 140]

Galium bifolium Wats. Low mountain bedstraw. Occasional to common in exposed areas or beneath other mountain plants, Frissell and Carpenter Mountains, ABAM zone.

Galium oreganum Britt., Oregon bedstraw. Common in forests and cutover areas, ABAM zone, occasional TSHE zone.

Galium trifidum L. var. *pacificum* Wieg., small bedstraw. Occasional, swampy areas, both zones. [F&D 63]

Galium triflorum Michx., fragrant bedstraw. Occasional to common, moist forests and cutovers, TSHE zone. [F 443, D 23]

Sherardia arvensis L., blue field madder. Introduced, observed on cutover area, TSHE zone.

Caprifoliaceae

Linnaea borealis L. var. *longiflora* Torr., American twinflower. Common to abundant, forests and cutovers, TSHE and lower ABAM zones.

Lonicera ciliosa (Pursh) DC., orange honeysuckle. Occasional, dry forests and cutover areas, TSHE zone. [F&D 77]

Sambucus cerulea Raf., blue elderberry. Occasional, wet areas, clearcuts or forest openings, both zones.

Sambucus racemosa L. ssp. *pubens* (Michx.) House var. *arborescens* (T. & G.) Gray, red elderberry. Occasional, wet portions of cutovers or forest openings, ABAM zone. [F&D 68]

Symphoricarpos albus (L.) Blake var. *laevigatus* (Fern.) Blake, snowberry. Occasional, dry forests and cutovers, both zones. [F&D 125]

Symphoricarpos mollis Nutt. in T. & G. var. *hesperius* (G. N. Jones) Cronq., creeping snowberry. Occasional to common, dry forests and cutovers, TSHE zone.

Valerianaceae

Plectritis congesta (Lindl.) DC., rosy plectritis. Rare, rock outcrops, TSHE zone. [F&D 92]

Valeriana scouleri Rydb., Scouler's valerian. Collected in cutover area, TSHE zone. [D 30]

Valeriana sitchensis Bong., northern valerian. Occasional to common, bogs, wet meadows and forests, ABAM zone. [F&D 113]

Campanulaceae

Campanula scouleri Hook. ex A. DC., Scouler's campanula or bell flower. Occasional to common, forests and cutover areas, both zones. [F&D 122]

Compositae

Achillea millefolium L. ssp. *lanulosa* (Nutt.) Piper var. *lanulosa* (Nutt.) Piper, yarrow. Occasional to common, mountain meadows, open forests, and cutover areas, both zones. [F&D 6, D 38]

Adenocaulon bicolor Hook., trail plant. Occasional, forests, both zones.

Agoseris aurantiaca (Hook.) Greene var. *aurantiaca*, slender agoseris. Common, rock outcrops and dry meadows, ABAM zone; occasional, cutover areas and rock outcrops, TSHE zone. [F 785, F&D 10, F&D 129, D 51]

Agoseris grandiflora (Nutt.) Greene, large-flowered agoseris. Occasional, cutover areas, rock outcrops, and dry meadows, both zones.

Agoseris heterophylla (Nutt.) Greene var. *heterophylla*, varied-leaved agoseris. Occasional to common, mountain meadows, ABAM zone. [F&D 206]

Anaphalis margaritacea (L.) B. & H., pearly everlasting. Occasional to common, cutover areas, both zones; occasional, boggy areas and mountain meadows, ABAM zone. [F 747]

Antennaria racemosa Hook., slender everlasting. Occasional, cutover areas and mountain meadows, both zones. [F 408]

Antennaria rosea Greene, rosy everlasting. Occasional, rock outcrops and dry meadows, ABAM zone. [F 783]

Anthemis cotula L., dog fennel. Introduced as bait, rare, TSHE zone.

Arnica amplexicaulis Nutt., clasping arnica. Collected in seepage areas, TSHE zone. [F&D 166]

Arnica cordifolia Hook. var. *cordifolia*, heart-leaved arnica. Collected on Frissell Mountain, ABAM zone. [H 481-2]

Arnica discoidea Benth. var. *eradiata* (Gray) Cronq., small-flowered arnica. Collected on cutover areas, TSHE zone. [D 6]

Arnica latifolia Bong. var. *latifolia*, broad-leaved arnica. Occasional to common, open forests, cutover areas, and mountain meadows, ABAM zone. [F 422]

Artemisia ludoviciana Nutt. var. *latiloba* Nutt., western wormwood. Local but often common in mountain meadows, Carpenter Mountain, ABAM zone.

Aster foliaceus Lindl. in DC., leafy aster. Occasional in mountain meadows, Frissell Mountain, ABAM zone.

Aster ledophyllus Gray, Cascades aster. Occasional, open forests, forest openings, and mountain meadows, ABAM zone. [F 655, F&D 117]

Aster oregonensis (Nutt.) Cronq., white-topped aster. Occasional, cutovers and roadsides, TSHE zone. [M 15]

Aster radulinus Gray, rough-leaved aster. Occasional to common, disturbed areas, ABAM zone. [F&D 123, F&D 202]

Chrysanthemum leucanthemum L., ox-eyed daisy. Introduced, occasional, cutovers and roadsides, TSHE zone. [F 547]

Cirsium arvense (L.) Scop., Canada thistle. Introduced, occasional to common, cutovers, TSHE zone.

Cirsium brevistylum Cronq., Indian thistle. Occasional to common, cutovers, TSHE zone. [M 6]

Cirsium centaureae (Rydb.) K. Schum., slender mountain thistle. Occasional to common, forest openings, cutovers, mountain meadows, and boggy areas, ABAM zone. [F 757, F&D 102, F&D 196]

Cirsium vulgare (Savi) Airy-Shaw, common or bull thistle. Introduced, occasional to common, cutovers, both zones.

Conyza canadensis (L.) Cronq. var. *glabrata* (Gray) Cronq., horseweed. Occasional to common, cutover areas and roadsides, TSHE zone. [D 53, D 68]

Crepis setosa Haller f., bristly hawksbeard. Introduced, collected on cutover areas, TSHE zone. [D 55]

Erigeron aliceae Howell, Alice's erigeron or fleabane. Occasional to abundant, forest openings, mountain meadows, and boggy areas, ABAM zone. [F 428, F 433, F&D 114]

Erigeron cascadensis Heller, Cascade erigeron or fleabane. Occasional, dry meadows, ABAM zone. [F&D 192]

Erigeron foliosus Nutt. var. *confinis* (Howell) Jeps., leafy erigeron. Occasional in exposed rock crevices on ridgetops, Frissell Mountain, ABAM zone. [H 483-3]

Eriophyllum lanatum (Pursh) Forbes, common woolly sunflower. Occasional to common, forest openings, cutovers, and mountain meadows, ABAM zone. [F 413, F 509, F&D 119]

Gnaphalium microcephalum Nutt. var. *thermale* (E. Nels.) Cronq., slender cudweed. Occasional to common, cutover areas, TSHE zone.

Gnaphalium purpureum L. var. *purpureum*, purplish cudweed. Collected in disturbed area near entrance (Lower Lookout Creek), TSHE zone. [D 70]

Haplopappus hallii Gray, Hall's haplopappus. Occasional on Lithosols, open south or west slopes, Frissell Mountain, ABAM zone. [H 494-6, H 482-2]

Hieracium albiflorum Hook., white-flowered hawkweed. Occasional, dry forests and common on cutover areas, both zones.

Hieracium cynoglossoides Arv.-Touv., houndstongue hawkweed. Occasional to common, open forests, cutovers, and mountain meadows, ABAM zone. [F 508, F 784, F&D 126, F&D 193, F&D 214]

Hieracium scouleri Hook. var. *scouleri*, Scouler's hawkweed. Observed on Carpenter and Frissell Mountains, ABAM zone.

Hypochaeris radicata L., hairy catsear or false dandelion. Introduced, occasional, disturbed areas, both zones. [F&D 160]

Lactuca biennis (Moench.) Fern., tall blue lettuce. Collected on cutover areas, TSHE zone. [D 62]

Lactuca muralis L., wall lettuce. Introduced, collected on disturbed area, TSHE zone. [D 5]

Lactuca serriola L., prickly lettuce. Introduced, collected on cutover area, TSHE zone. [M 17]

Luina stricta (Greene) Robb., rainiera. Occasional, mountain meadows on Carpenter Mountain, ABAM zone. [F 341]

Madia gracilis (Smith) Keck, common tarweed. Occasional to common, cutover areas and roadsides, TSHE zone. [F&D 51, F&D 74, D 66]

Madia madioides (Nutt.) Greene, woodland tarweed. Occasional, dry forests and cutover areas, TSHE zone. [F&D 52, D 7]

Madia minima (Gray) Keck, least tarweed. Occasional, rock outcrops, both zones. [F 724]

Microseris nutans (Geyer) Schultz-Bip., microseris. Occasional, forest openings and mountain meadows, ABAM zone. [F&D 11, F&D 176]

Petasites frigidus (L.) Fries var. *palmatus* (Ait.) Cronq., western coltsfoot. Common, wet areas, including cutovers and roadsides, both zones. [F 52]

Rudbeckia occidentalis Nutt. var. *occidentalis*, western rudbeckia or coneflower. Occasional, mountain meadows and cutovers, ABAM zone. [F 654]

Senecio harfordii Greenm., Harford's senecio. Occasional, forests and cutover areas, both zones. [F&D 25, D 54]

Senecio integerrimus Nutt. var. *exaltatus* (Nutt.) Cronq., tall western senecio. Forest openings and mountain meadows, ABAM zone. [F 721, F&D 173]

Senecio jacobaea L., tansy ragwort. Introduced, occasional, disturbed areas, both zones. [D 69]

Senecio sylvaticus L., woodland groundsel. Introduced, occasional to abundant, cutover areas, both zones.

Senecio triangularis L., spear-head senecio. Common, boggy areas and mountain meadows, ABAM zone. [F 729, F 754, F&D 105, F&D 112, F&D 130]

Solidago canadensis L. var. *salebrosa* (Piper) Jones, narrow goldenrod. Occasional, boggy areas and mountain meadows, ABAM zone. [F 756, F&D 128]

Sonchus asper (L.) Hill, prickly sow-thistle. Introduced, cutover areas and roadsides, TSHE zone. [F&D 139, D 50, D 64]

Taraxacum officinale Weber in Wiggers, common dandelion. Introduced, cutover areas and mountain meadows, both zones. [F 722]

Tragopogon dubius Scop., large yellow goatsbeard. Introduced, occasional, cutover areas, both zones. [F&D 233, D 63]

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PNW-139 January 1971

COLLAPSE OF AN OUTBREAK POPULATION OF THE DOUGLAS-FIR TUSSOCK MOTH, *HEMEROCAMPA PSEUDOTSUGATA* (LEPIDOPTERA: LYMANTRIIDAE)

by

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and

C. G. Thompson, *Principal Entomologist*

Keywords: Hemerocampa pseudotsugata, Douglas-fir tussock moth, Abies concolor, virus diseases (insects), forest insects, insect populations, Modoc National Forest, Calif.

ABSTRACT

An outbreak population of the Douglas-fir tussock moth on white fir was studied during the summer of its collapse. Survivorship curves and a partial life table were prepared which illustrate the pattern of the population decline. The major cause of collapse was a natural epizootic of virus disease in the larval population. However, a late spring frost which destroyed much of the preferred food of early-instar larvae may have also contributed significantly. Density of early-instar larvae declined more sharply in heavy than in light population areas which suggests that larval survival was partially density-dependent.

INTRODUCTION

Outbreaks of the Douglas-fir tussock moth, *Hemerocampa pseudotsugata* McD., occur periodically in the true fir, *Abies* spp., and Douglas-fir, *Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco, forest in western North America. Tussock moth populations build up inconspicuously over a period of years until a defoliation threshold is reached when they may suddenly cause unexpected extensive damage. When a damaging outbreak does occur, the tussock moth population may remain at a level causing heavy defoliation for from 1 to 3 years, after which the population usually abruptly declines. Most tussock moth infestations that are allowed to run their natural course seem to be terminated eventually by an epizootic of nucleopolyhedrosis virus (Hughes and Addison 1970).[1/] Unfortunately, outbreaks seldom end before they have caused considerable tree damage (Wickman 1963).

In 1965, an outbreak of tussock moth on white fir, *Abies concolor* (Gord. and Glend.) Lindl. was detected over a 450-acre area in Modoc County in northern California. In 1966, the larval population was studied from eclosion in early June until August when virtually all larvae vanished just prior to pupation. For 2 years thereafter, no larvae were recovered from sampling in the area.

In this paper, population data are presented which document the natural decline of larvae in this outbreak. An analysis is also made of some of the factors which seemed to influence the collapse.

METHODS

Description of the Area and Study Points

The outbreak was located in the general boundaries of the Modoc National Forest in California. The forest type was predominantly an overstory of old-growth ponderosa pine, *Pinus ponderosa* Laws., in association with a heavy understory of white fir.

Eight study points were established in the infestation (fig. 1). Five were in the center zone of heaviest defoliation (more than 30 percent) and three in transition zones of lesser defoliation (less than 30 percent). Ten white fir trees were selected at each point from which successive samples were taken during the study period.

Population Sampling

The larval population in the vicinity of each point was evaluated biweekly during June and July 1966 by estimating the mean density of larvae per thousand square inches of branch area on the 10 sample trees. Density was estimated by tallying the number of larvae on six 17-inch twigs taken systematically from three crown levels of each sample tree at the point. Counts of larvae on the twigs were weighted according to the distribution of foliage in the tree. The standard error of the mean density of larvae at each point was within 20 percent. Methods for sampling and evaluating tussock moth populations have been reported in more detail (Mason 1970).

Parasites and Disease

Mortality of larvae from parasites and disease was determined for the infestation as a whole from biweekly collections of larvae at 25 sampling stations.

[1/] *B. E. Wickman, G. C. Trostle, and P. E. Buffam. Douglas-fir tussock moth. Forest Pest Leafl. 86 (rev.). USDA Forest Serv. In press.*

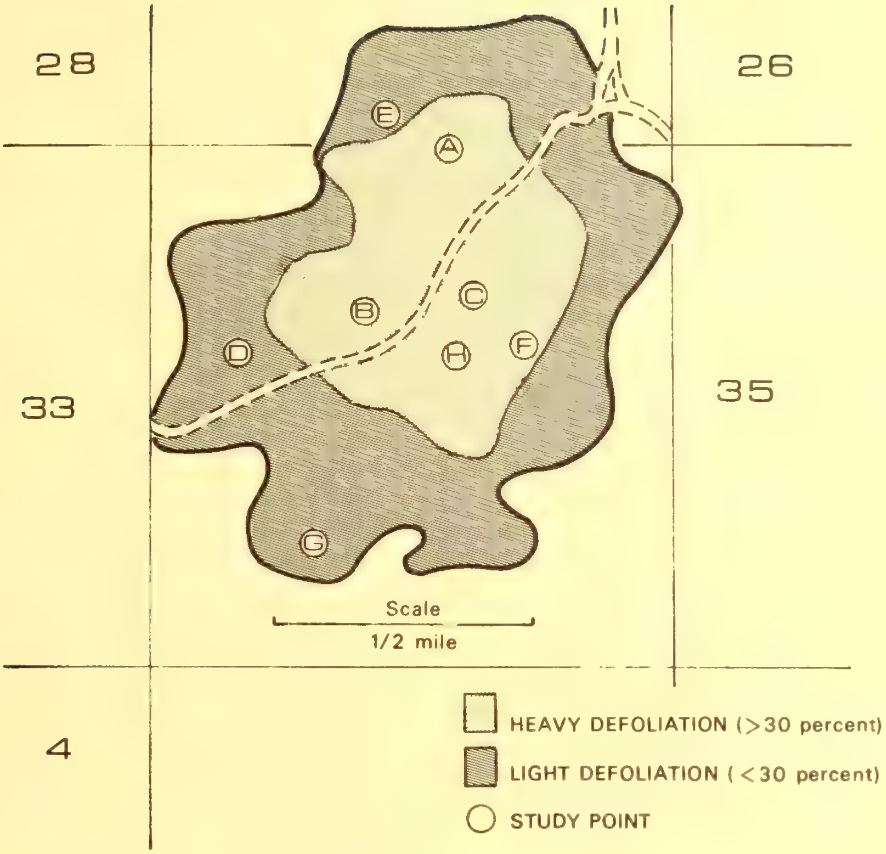
28
26
33
35
4
E
A
B
C
D
H
F
G
Scale
1/2 mile
HEAVY DEFOLIATION (>30 percent)
LIGHT DEFOLIATION (<30 percent)
STUDY POINT

Figure 1.--*Map of 1966 outbreak of the Douglas-fir tussock moth, Modoc County, Calif.*

Collected larvae were reared singly under aseptic conditions at the Forestry Sciences Laboratory at Corvallis, Oreg. Cause of death was determined in each instance. Although the data from the laboratory rearings are believed to represent a reasonably close approximation of the prevalence of polyhedrosis in the field, the differences in environmental and nutritional conditions might be expected to produce some differences from the actual field prevalence.

RESULTS

Survivorship Curves and Partial Life Table

Two survivorship curves were constructed for larvae by pooling separately the data from points in the heavily infested area and the data from the points in the lightly infested area. The decline of the mean density of larvae at points in the two areas through the summer is shown in figure 2. In general, the distribution of survivorship in both areas had a concave form, implying that mortality rate was relatively constant for all age groups of larvae. The logarithm of larval density in each area plotted over time would be roughly a diagonal straight line where mortality is relatively constant for all ages of larvae. This would be the Type II form of survivorship described by Deevey (1947).

Study points in the area of heaviest defoliation showed a particularly sharp decline in number of first-instar larvae. As a result, larval density at points in both the heavy and light areas approached a similar density level by the third instar. Thereafter, population decline occurred at a more constant rate at all points. Field sampling was discontinued after July 25, 1966, when the few

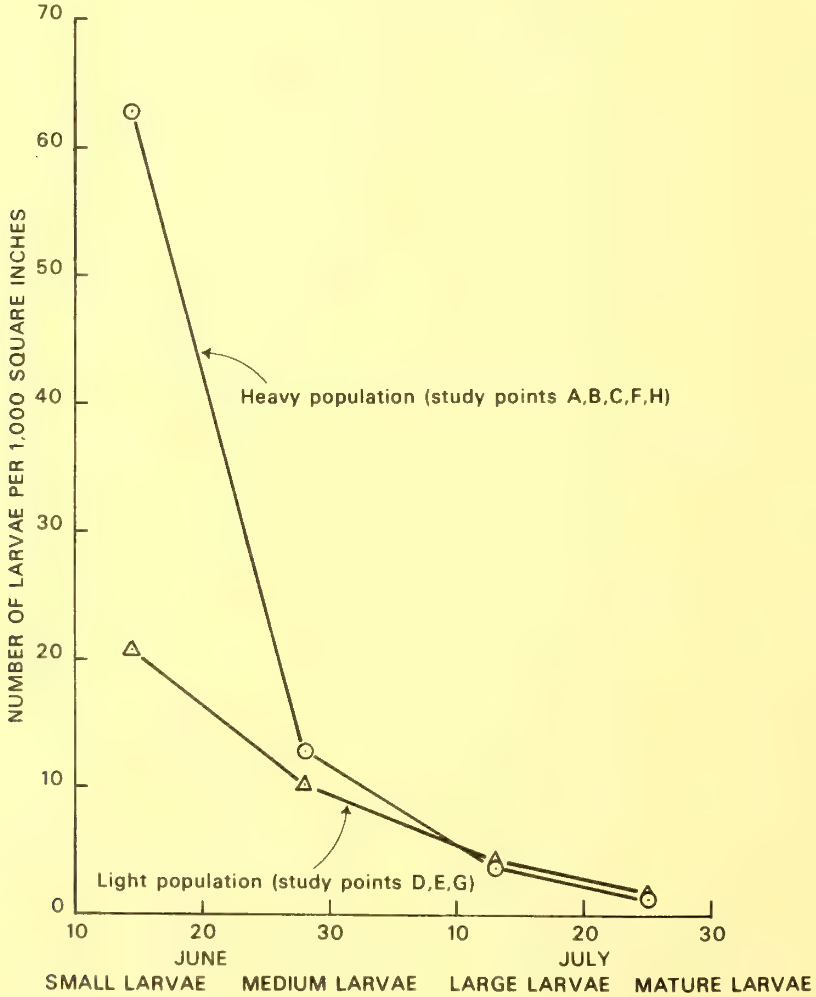

Figure 2.--*Survival of tussock moth larvae in areas of two different population intensities during 1966.*

remaining larvae reached maturity. However, it is safe to assume that all density values must have dropped to near zero by early August because no pupae could be found after considerable searching.

A general life table has been prepared for eggs and larvae by pooling data from all of the study points (table 1). This was constructed after Morris and Miller's (1954) format. It is a useful way of illustrating average decline in the outbreak in relation to the mortality factors responsible. Since an accurate estimate of number of eggs was not available, a minimum egg density value for the table was calculated by adding mortality that occurred during the first age interval to the first larval sample.

Over the course of the entire larval stage, virus disease accounted for 41-percent mortality and was the major cause of death in the population. Egg and larval parasites combined accounted for another 23-percent mortality. A relatively large proportion (34 percent) of the loss was unaccountable in the life table.

A late spring frost about the time of egg hatch killed much of the tender new foliage on white fir so that there was a scarcity of the preferred food of young larvae. This probably caused starvation of some early-instar larvae (Mason and Baxter 1970). It also seemed to stimulate excessive larval dispersal by wandering or ballooning on silk threads; likewise, this may have increased the probability of predation. Early in the cycle, these losses undoubtedly were responsible for much of the unaccountable mortality which, at that time, exceeded the loss caused by virus disease. However, later in the cycle they accounted for proportionately less mortality as the incidence of virus increased.

The final density of mature larvae was probably considerably lower than the calculated value of 1.0 in the table because no pupae were observed in the field. As the season progressed, fewer larvae were available in the field for sampling virus disease; therefore, the estimate of disease incidence became less reliable toward the end of the cycle and could easily have been underestimated.

Two species of ichneumonid parasites were responsible for most of the larval parasitism recorded. Their impact on the population could have been considerably greater than indicated by the life table because some female adults in this family may also feed on other larvae before ovipositing. This would be a form of predation by the adult parasite that could not be determined from larval rearings.

Analysis of Survival

Study points in the infestation were especially useful when they were treated as replicates and each point analyzed as a separate population. For the most part it was realistic to assume that the points contained relatively independent populations during the larval stage. Regression analyses were then performed which revealed certain processes involved during the decline of the outbreak.

Table 1.--*Partial life table for 1966 generation of Douglas-fir tussock moth at Corral Creek, California*

Sample date	Age interval (x)	Number alive at start of x (per 1,000 square inch) (l_x)	Factors responsible for d_x (d_xF)	Number dying during x (d_x)	d_x as percentage of l_x ($100q_x$)
May 24	Eggs	[1](61.9)	Egg parasites	7.4	12
			Virus disease of 1st-instar larvae	6.2	10
			Larval parasites	1.2	2
			Subtotal	14.8	24
June 12-17	Small larvae (1st instar)	47.1	Virus disease	13.2	28
			Larval parasites	4.2	9
			Unaccountable	18.0	38
			Subtotal	35.4	75
June 27-30	Medium larvae (1st, 2d, and 3d instars)	11.7	Virus disease	4.6	39
			Larval parasites	1.0	9
			Unaccountable	2.2	19
			Subtotal	7.8	67
July 11-15	Large larvae (3d, 4th, and 5th instars)	3.9	Virus disease	1.4	35
			Larval parasites	.3	9
			Unaccountable	.9	23
			Subtotal	2.6	67
July 25-27	Mature larvae (5th and 6th instars)	1.3	Virus disease	.2	15
			Larval parasites	.1	8
		[1](1.0)			
			Summary of mortality:		
			Virus disease	25.6	41.3
			Egg parasites	7.4	12.0
			Larval parasites	6.8	11.0
			Unaccountable	21.1	34.1
			Total	60.9	98.4

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[1] Values calculated from mortality data.

Survival of larval populations from one sampling period to the next was investigated using the expression $S = S_S \times S_M \times S_L$ where S is the proportion of the larval population surviving to mature larvae and S_S, S_M, and S_L are age interval survival estimates of small, medium, and large larvae, respectively. Survival estimates were calculated at each study point from the mean density values of the four larval samplings ($N_1 \ldots N_4$) by $S_S = N_2/N_1$, $S_M = N_3/N_2$, and $S_L = N_4/N_3$. These estimates are given in table 2.

The analysis made was similar to that described by Watt (1963) and Morris (1963) but was modified because of incomplete generation data. Survival data were first transformed to logarithms to improve linearity and stabilize variance. Then a series of simple linear regressions were calculated to determine which of the age interval survivals (S_S, S_M, S_L) contributed most to variation in total larval survival.

The results in table 3 show that survival of small and large larvae was each significantly related to total survival. Of these, survival of small larvae accounted for most of the variation in overall survival (74 percent). These correlations are useful as a tool to detect the stage of development during which mortality factors are most influential in establishing the form of population decline.

As survival of small larvae seemed to have the most influence on the final value of larval

Table 2.--*Initial density (N_1), age interval survival (S_S, S_M, S_L), and total survival to mature larvae (S) at each study point*

Study point	N_1	S_S	S_M	S_L	S
	Number per 1,000 sq. in.	- - - - - - - -	-*Proportion*	- - - - - - -	
C	76.9	0.077	0.169	0.200	0.003
F	64.7	.187	.256	.516	.025
A	64.4	.562	.276	.320	.050
B	58.0	.043	.560	.143	.003
H	50.7	.136	.391	.111	.006
E	27.7	.520	.583	.357	.108
D	20.4	.588	.210	.600	.074
G	13.8	.261	.556	.250	.036
Mean	47.1	.297	.375	.325	.038

Table 3.--*Regression statistics of larval survival*

Dependent variable	Independent variable	r	r^2
S	S_S	[1] 0.860	0.740
S	S_M	-.236	.056
S	S_L	[1] .784	.615

[1] Significant at the .01 level.

survival, this stage should be examined further. From figure 2 it can be seen that the decline of mean density of small larvae was sharpest at the study points in the area of the heaviest population. A negative relationship seems to exist when small larval survival is plotted over initial mean density and a logarithmic curve fitted to the data (fig. 3). Although too few observations were available to establish a significant correlation, the graphical relationship shows that mortality factors were usually more active at high than at low population density. Therefore, survival of small larvae was probably density-dependent. This is not surprising when the major causes of mortality at that stage are considered (table 1). Starvation, loss from dispersal, and virus disease would all tend to be more pronounced at high than at low population densities. Later in the summer, as overall density of larvae declined and as virus disease spread through the entire infestation, there was no detectable relationship between density and survival.

CONCLUSIONS AND DISCUSSION

The collapse of the outbreak seemed to be due largely to the extensive mortality from virus disease. Although a shortage of food occurred which may have caused some starvation and exceptional dispersal losses of young larvae, the overriding factor in the collapse was disease.

For the infestation as a whole, the average rate of virus mortality was relatively constant in all larval stages. However, at different study points the variation in decline of early-instar larvae appeared density-dependent. Circumstantial evidence indicates that this variation could have been due to differential incidence and spread of virus early in the summer. Added stress to the population caused by food shortage could also have influenced the course of the epizootic.

The pattern of decline in this outbreak will be useful in interpreting other tussock moth infestations. Current studies in

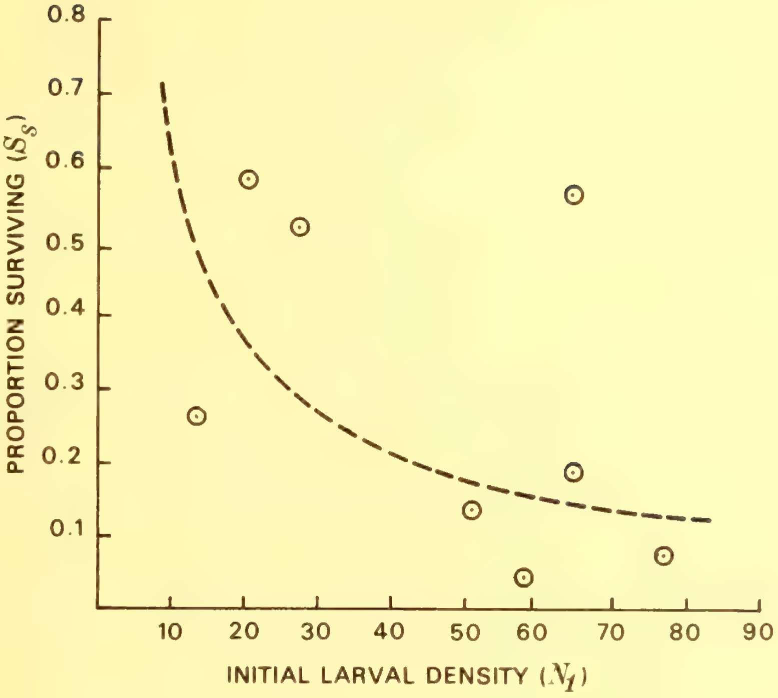

Figure 3.--*Relationship between survival of small larvae* (S_s) *and initial larval density* (N_1). *Curve is fitted from the logarithmic linear relationship.*

tussock moth population dynamics indicate that survivorship of larvae could be a key to distinguishing infestation trend. For example, larval survival during the declining stage of this outbreak averaged 3.8 percent (table 2); however, survival in disease-free populations that are increasing has averaged more than 20 percent. Eventually, it may be possible to use such survivorship data in research as an index to increasing or decreasing populations and for evaluation of forest conditions in relation to tussock moth outbreaks.

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MIRROR STEREOSCOPE PARALLAX WEDGE

by H. Gyde Lund, *Associate Photogrammetrist*

Keywords: Photogrammetry, aerial photography, parallax, mensuration, photo interpretation.

ABSTRACT

Modification of a conventional parallax wedge for use with a mirror stereoscope is described.

Mirror stereoscopes have two distinct advantages over lens-type stereoscopes: (1) the entire stereo model can be viewed without moving the photos and (2) height measurements on 9- by 9-inch photos can be made without cutting. A major disadvantage is the general lack of inexpensive photogrammetry tools that can be used with mirror stereoscopes. However, a simple and economical device for measuring heights can be made in about half an hour by modifying a standard parallax wedge, such as the U.S. Forest Service's version for mountainous areas.[1/] The cost would be less than \$5 compared with \$150 for a parallax bar.

The parallax wedge is basically a pair of converging lines with which one measures the distance that a point on one photo (i.e., top of an object) is separated from the same image point on the conjugate stereo photo. The top and bottom ends of the converging lines are a precisely measured distance apart. The bottom distance between lines is greater than the top by about 1 inch. The distance between any two corresponding points on the converging lines is printed on a scale located on the right-hand line. Heights are obtained by subtracting the separation reading at the top of an object from the reading at the object's base and applying this parallax *difference* to a height formula.

[1/] Karl E. Moessner and S. Ross Tocher. Parallax wedge improved. USDA Forest Serv. Intermountain Forest & Range Exp. Sta. Res. Note 94, 2 pp. 1962.

The differences between the two readings, not the readings per se, are essential for height determinations.

The average separation of corresponding points on adjacent photos corresponds to the distance between the viewing lenses. Therefore, the wedge is designed for a particular type of stereoscope. The most commonly used wedge for a lens stereoscope can directly measure photo point separations ranging from 2 inches to approximately 3 inches; however, the common wedge cannot be used with the mirror stereoscope because the lines are too close together. Most mirror stereoscopes have a photo point separation of approximately 8.25 inches. To make the parallax wedge usable with the mirror stereoscope, the lines should have an average separation of 8.25 inches. The separation of the modified wedge would be 7.75 inches at the top and 8.75 inches at the bottom to be the equivalent of a standard wedge with 2- and 3-inch separations.

Materials for construction of the mirror-stereoscope wedge are:

1 piece heavy acetate, 10 by 12 inches
1 ruler graduated in 100th's of an inch (Pickett No. 33E)[2]
12-inch ruler
needle or scribe
grease pencil
transparent tape
1 standard parallax wedge for mountainous areas[3]

The procedure for modifying the wedge is as follows:

1. Draw a fine line lengthwise down the middle of the 10- by 12-inch acetate.

2. Center the acetate over the wedge and scribe a line through the uppermost pair of separation readings of the wedge and another through the lowermost pair of separation readings onto the acetate (fig. 1A).

3. Subtract the reading at the top of the wedge from the bottom and divide by 2:

Top = 2 inches
Bottom = 2.9 inches
Difference = 0.9 inch
Quotient = 0.45 inch

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[2] Mention of trade names or products does not imply endorsement by the U.S. Department of Agriculture.

[3] Available through Regional Forester, USDA Forest Service, R-4, 324 25th Street, Ogden, Utah 84401.

4. Subtract the quotient from the desired average separation (i.e., separation distance of stereoscope to be used) for the new top reading and add the quotient to the desired average separation for the new bottom reading:

Desired average separation = 8.25 inches
New top separation = 8.25 - 0.45 = 7.80 inches
New bottom separation = 8.25 + 0.45 = 8.70 inches

5. Divide the new top and bottom separations in half:

7.80/2 = 3.90 inches
8.70/2 = 4.35 inches

6. Mark off the distance found in step 5 on each side of the center line along the respective top and bottom scribed line.

7. Cut wedge in half lengthwise.

8. Mount each half of wedge on the underside of the acetate so that the top and bottom of each half correspond with the points marked off in step 6 (fig. 1B).

The photos should be prepared for height measurements in the usual manner, except that the distance between the principal point and the conjugate principal point should be 8.25 inches. The wedge separation has been increased 5.80 inches throughout. Even though no change has been made in the labeling on the wedge (i.e., where the wedge indicates 2 inches, the actual distance is 7.80 inches), the *differences* in parallax readings will be correct.

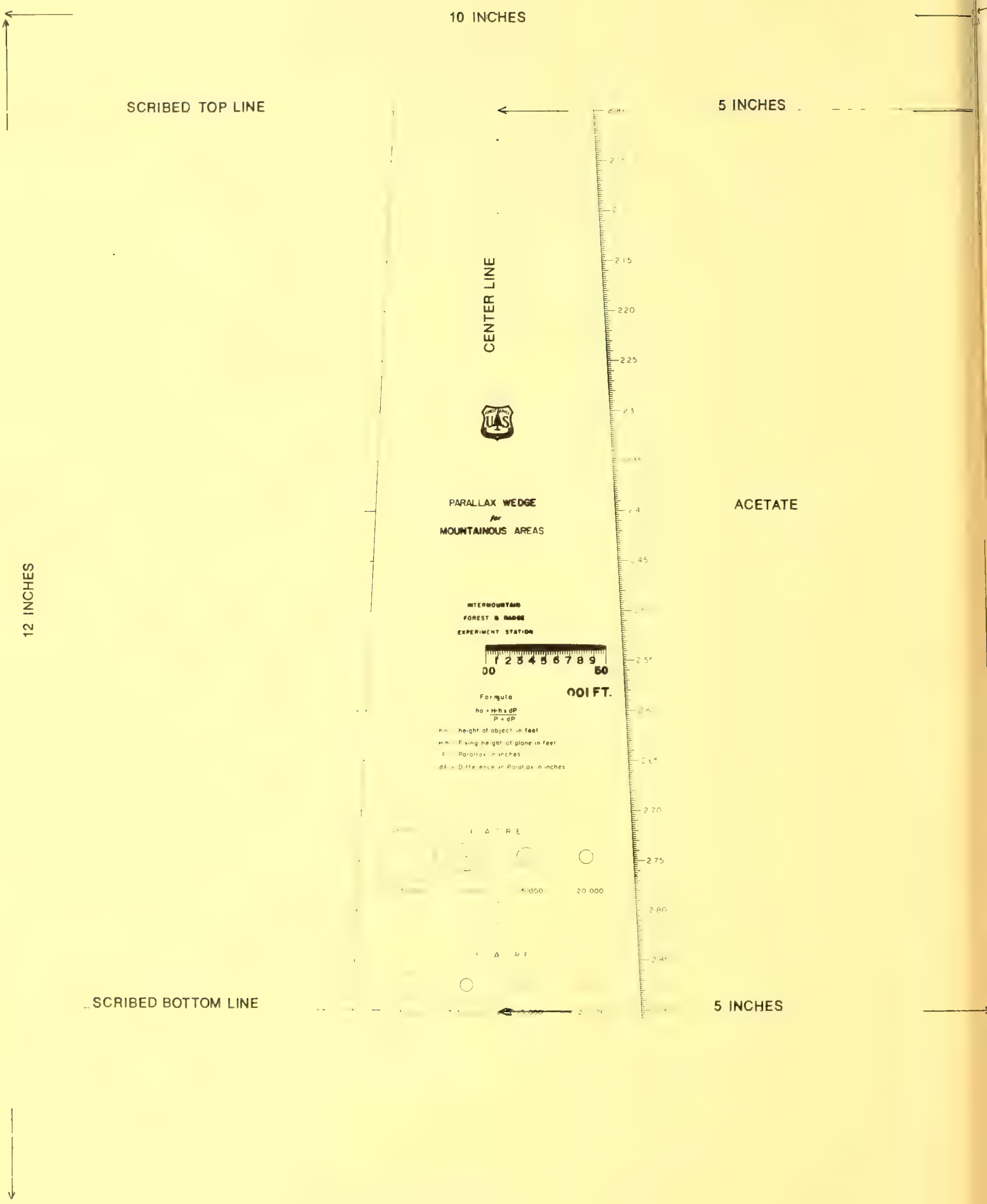

Figure 1A.--*Construction of a mirror parallax wedge: Acetate is centered on wedge; top and bottom lines are scribed.*

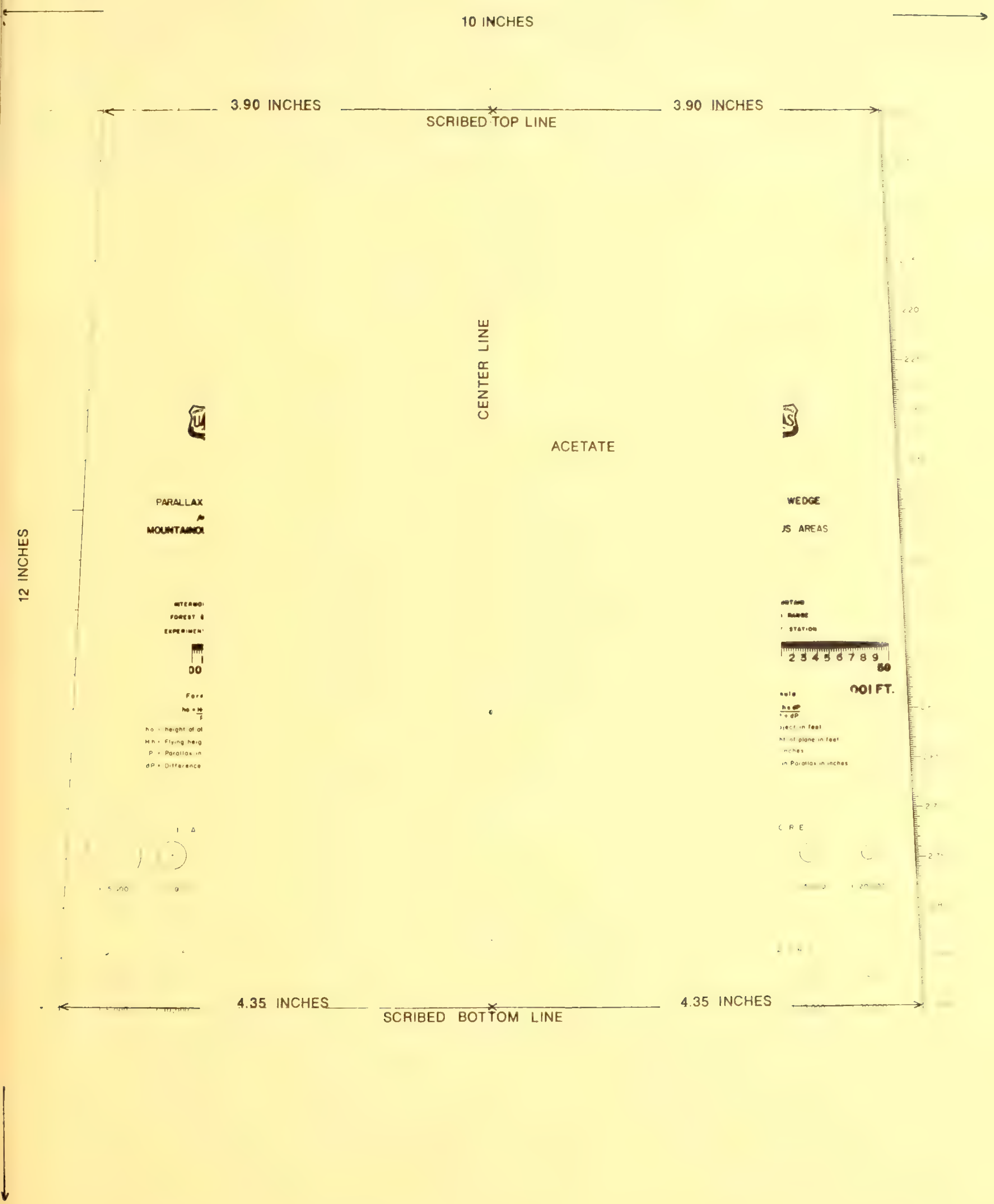

Figure 1B.--*Construction of a mirror parallax wedge: Wedge is split apart and taped to acetate at proper distance along top and bottom.*

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FIFTY-FIVE-YEAR-OLD LODGEPOLE PINE RESPONDS TO THINNING

by

Walter G. Dahms
Principal Silviculturist

Abstract

Diameter growth of 55-year-old lodgepole pine trees released by thinning was substantially greater than unreleased trees in relative terms. Presumed release effect was sufficient to prevent a significant volume increment loss on thinned plots. However, absolute diameter growth was small because diameter growth capability of 55-year-old lodgepole pine trees is limited.

Keywords: Forest thinning, Pinus contorta, *lodgepole pine, tree growth, stand increment estimates, tree diseases, Pringle Falls Experimental Forest, Oreg.*

Harvested wood from lodgepole pine (*Pinus contorta*)[1] forests is only a small fraction of the total wood grown by these forests.

In most instances, more wood from wild stands is lost on trees that fail to reach usable size than is harvested. Natural stands growing on average sites on the Deschutes National Forest frequently yield 5,000 to 6,000 board feet per acre at age 100 years. However, these sites are capable of producing 6,000 to 7,000 cubic feet of wood in 100 years (Dahms 1964). Thus, less than 1 board foot is

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[1] Authorities for common and scientific names of trees, grasses, and shrubs and herbs are Little (1953), Hitchcock and Chase (1950), and Kelsey and Dayton (1942).

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actually harvested for each cubic foot of potential wood production. A program of timely thinnings, designed to capture a larger share of the potential yield and enhance stand vigor, should greatly increase production of usable lodgepole pine wood.

A thinning study installed in 1934 in a 55-year-old lodgepole pine stand on the Pringle Falls Experimental Forest, about 35 miles south of Bend, Oregon, provides us with an opportunity to look at total wood production and see what happens to it over a 32-year period. Even though stand density control was not begun soon enough for optimum results, it is possible to visualize what might have happened with earlier thinnings. Furthermore, as we start piecing together managed-stand performance from thinning studies in stands of various ages for an entire rotation, results from this study in an older stand probably will become increasingly valuable.

EXPERIMENTAL CONDITIONS

The *experiment* consists of three 1/2-acre plots. Two were thinned, one to a 12- by 12-foot average spacing and the other to 16 by 16 feet. The third was left as an unthinned control. The *site* is a level, low-lying, poorly drained area. Leading understory plants are bearberry (*Arctostaphylos urva-ursi*), Idaho fescue (*Festuca idahoensis*), strawberry (*Fragaria cunefolia*), and patches of lodgepole pine reproduction. The Wickiup soil found here is typical of poorly drained conditions. It usually supports climax lodgepole pine. Site index for the three plots averaged 57, slightly above average for central Oregon. (Site index represents average height of the five tallest trees per acre at index age 50 years (Dahms 1964).)

The *stand* is essentially even-aged, with an average of 55 years at the time the study was begun in 1934. A high percentage of all trees were infected with rust diseases. W. H. Beeman commented in his 1936 establishment report:[2]

> During the establishment of these plots it was difficult to pick out the healthiest trees because of the presence of fungus diseases throughout the stand. The most conspicuous rust was *Cronartium stalactiforme* [*Peridermium stalactiforme*] which formed a canker often extending almost the entire length of the bole. ... Another

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[2] W. H. Beeman, Jr. First progress report on Pringle Falls lodgepole pine thinning plots numbered 11, 12, and 13. (Unpublished typewritten report on file at the Bend Silviculture Laboratory dated Apr. 1, 1936.)

rust occurring on most of the trees was western pine gall (*Cronartium harknesii* [*P. harknesii*]). Almost all dead trees and those lacking in vigor were infected by one or both of these diseases. Although the healthiest trees were left, 67 percent of these were attacked.

The *kind of thinning* done in 1934 was only briefly mentioned in Beeman's report. However, McKay, in his 1942 report, stated that leave trees had been chosen mainly on the basis of spacing with little regard for size or vigor.[3]

Plots were not entirely comparable at the start of the experiment. Initially, basal area, average diameter, and cubic volume were all somewhat greater on the plot later thinned to the 12- by 12-foot spacing (table 1). Similarly, all these measures indicate that the plot thinned to the 16- by 16-foot spacing had the least basal area and volume. Although these differences were real, it would be difficult to find three plots more closely alike.

Treatments are not replicated, and we have no measure of plot-to-plot difference not associated with treatment; nevertheless, the experiment does give us a good clue as to growth possibilities under management.

RELATION TO PAST WORK

Barrett (1961) reported a good response of individual tree growth to increased growing space during the first 22 years. Our period of observation extends another 10 years, and trends from one measurement period to another are examined.

Volume and volume increment results differ from those presented by Barrett because a different volume formula was used (see footnote 4, table 1). The new volume formula provides for complete comparability with that used in gross and net yield tables for lodgepole pine (Dahms 1964).

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[3] Donald F. McKay. First progress report on Pringle Falls plots 11, 12 and 13 — thinning in lodgepole pine. (Unpublished typewritten report on file at the Bend Silviculture Laboratory dated Mar. 31, 1942.)

Table 1.--*Statistics before thinning, after thinning, and 32 years later--per acre basis*[1]*--for lodgepole pine*

Stand age and treatment	Number of trees	Average d.b.h.[2]	Average height[3]	Stand density			Volume	
				Basal area	Bole area[4]	CCF[5]	Cubic[4]	Scribner
		Inches	*Feet*	*Square feet*			*Cubic feet*	*Board feet*
55, before thinning:								
Thinned 16 by 16 feet	574	5.1	45	92.7	21,169	112	1,939	1,471
Thinned 12 by 12 feet	616	5.5	47	116.3	25,386	146	2,606	2,809
Unthinned	630	5.1	45	101.1	23,208	133	2,232	1,464
55, after thinning:								
Thinned 16 by 16 feet	164	6.7	50	42.6	8,729	50	992	782
Thinned 12 by 12 feet	298	6.6	50	78.1	16,211	91	1,906	2,646
Unthinned	630	5.1	45	101.1	23,208	133	2,232	1,464
87: Thinned 16 by 16 feet	110	10.8	68	74.2	12,587	71	2,268	9,660
Thinned 12 by 12 feet	198	10.0	67	113.7	21,051	112	3,484	12,978
Unthinned	364	6.9	54	108.1	22,920	121	2,967	7,552

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[1] All statistics are for trees 2.6-inch d.b.h. and larger unless otherwise stated.

[2] The arithmetic average of all diameters.

[3] Height of the tree of average diameter as read from a height over diameter curve.

[4] Volume and bole area formulas were derived from 190 trees felled and measured for volume table purposes as a part of the gross and net yield table project. The three volume formulas used are:

a. Volume in cubic feet = $0.031 + 0.002589D^2H$ for D^2H values through 1,482,
b. Volume in cubic feet = $0.36 + 0.002366D^2H$ for D^2H values from 1,483-14,195,
c. Volume in cubic feet = $3.49 + 0.0021461D^2H$ for D^2H values of 14,196 and larger,

where D = diameter breast high outside bark and H = total height.

Total stem volume including stumps and tips is the quantity estimated by these equations.

The bole area formulas used are:

a. Bole area in square feet = $0.68 + 0.1591\ DH$ for DH values through 398.
b. Bole area in square feet = $4.82 + 0.1487\ DH$ for DH values of 399 and larger.

Total stem surface area inside bark including tips and stumps is the quantity estimated. This closely approximates stem cambium area.

[5] The formula crown competition factor (CCF) = $\frac{1}{A}\,[0.0192N + 0.0168\Sigma D + 0.0036\Sigma D^2]$ where A = plot area in acres, N = number of trees, and D = d.b.h. outside bark, was taken from Alexander, Tackle, and Dahms (1967).

[6] Board-foot volume is based on the Scribner table (Johnson 1952). All trees 8.6-inch d.b.h. and larger are included to a 5.0-inch top.

RESULTS

Diameter growth was fastest on the most heavily thinned (16- by 16-foot) plot and slowest on the unthinned one (table 2). During the 32-year period, growth of largest trees selected at the rate of 100 per acre ranged from 2.9 inches on the unthinned plot to 4.5 inches on the most heavily thinned area.

There was a strong tendency for diameter growth to slow with increasing age and for apparent thinning advantage to decrease with the passage of time (table 2). Although diameter growth was averaging less than 0.1 of an inch per year during the last period on all plots, a few healthy trees with good crowns were still growing 0.12 inch per year or better. These were trees that had not been infected with one of the rust diseases and that had good growing room provided through either thinning or natural death of nearby competitors.

There was almost no relationship between diameter and diameter growth during the 32-year period. The 100 largest trees per acre grew at about the same rate as all trees (table 2). Similarly, regressions of diameter growth on diameter calculated for each plot for each measurement period showed either no or only slight significant slope. Obviously, larger trees had grown more rapidly in the past, but by age 55 this relationship had disappeared.

Because of mortality and shifts in relative diameter, diameter growth of trees that survived through a given period, as shown in table 2, is not the same as average diameter increase obtained by subtracting the average beginning from the average ending diameter (table 1). For example, the 100 largest trees per acre in 1966 had averaged 0.14 inch per year, or 4.5 inches, during the preceding 32 years on the most heavily thinned plot. However, increase in average diameter of the 100 largest trees was only 3.6 inches during the same period.

Diameter distribution has been modified substantially by thinning (fig. 1). Many of the smaller trees died on the unthinned plot, but on the thinned plots they were removed more promptly and more completely. There was also a tendency for more trees of larger diameters to develop on the thinned plots.

Height of the leading trees on all plots was similar in 1966. However, height of the tree of average diameter increased much more rapidly on the thinned plots than on the unthinned one (table 1). The

Table 2.--*Periodic annual diameter growth*[1] *in thinned and unthinned lodgepole pine*

Period	Average 100 largest trees per acre			Average all trees		
	Thinned		Unthinned	Thinned		Unthinned
	16 by 16	12 by 12		16 by 16	12 by 12	
	- - - - - - *Inches* - - - - - -			- - - - - - *Inches* - - - - - -		
1935-39	0.19	0.12	0.10	0.19	0.13	0.08
1940-46	.18	.10	.08	.17	.11	.06
1947-51	.13	.10	.08	.12	.09	.06
1952-56	.15	.12	.09	.14	.11	.09
1957-61	.10	.08	.08	.10	.07	.06
1962-66	.08	.06	.07	.09	.06	.05
1935-66	.14	.10	.09	.14	.10	.08

[1] The diameter growth recorded here is averaged diameter increment for those trees that lived through the period in question. Included are ingrowth trees. Fewer trees are involved in the 1935-66 period than any of the others because it includes only those trees that lived through the entire period.

difference is explained by the many small trees on the unthinned plot pulling down the average diameter. Similarly the tree of average diameter was 5 feet taller after thinning than before on the most heavily thinned plot (table 1).

Height growth of the tallest trees closely approximated that predicted by site curves contained in the gross and net yield tables for lodgepole pine (Dahms 1964). Site index for the three plots as a group was 57.7 in 1934 and 57.0 in 1966.

Basal area increment showed a general downward trend with increasing age as might be expected (table 3). The brief reversal of this trend during the 1952-56 period evidently reflected significantly better than average growing conditions and paralleled a similar trend in volume increment during the same period.

Mortality offset nearly half of the gross basal area increment on the two thinned plots, but 89 percent was lost on the unthinned plot.

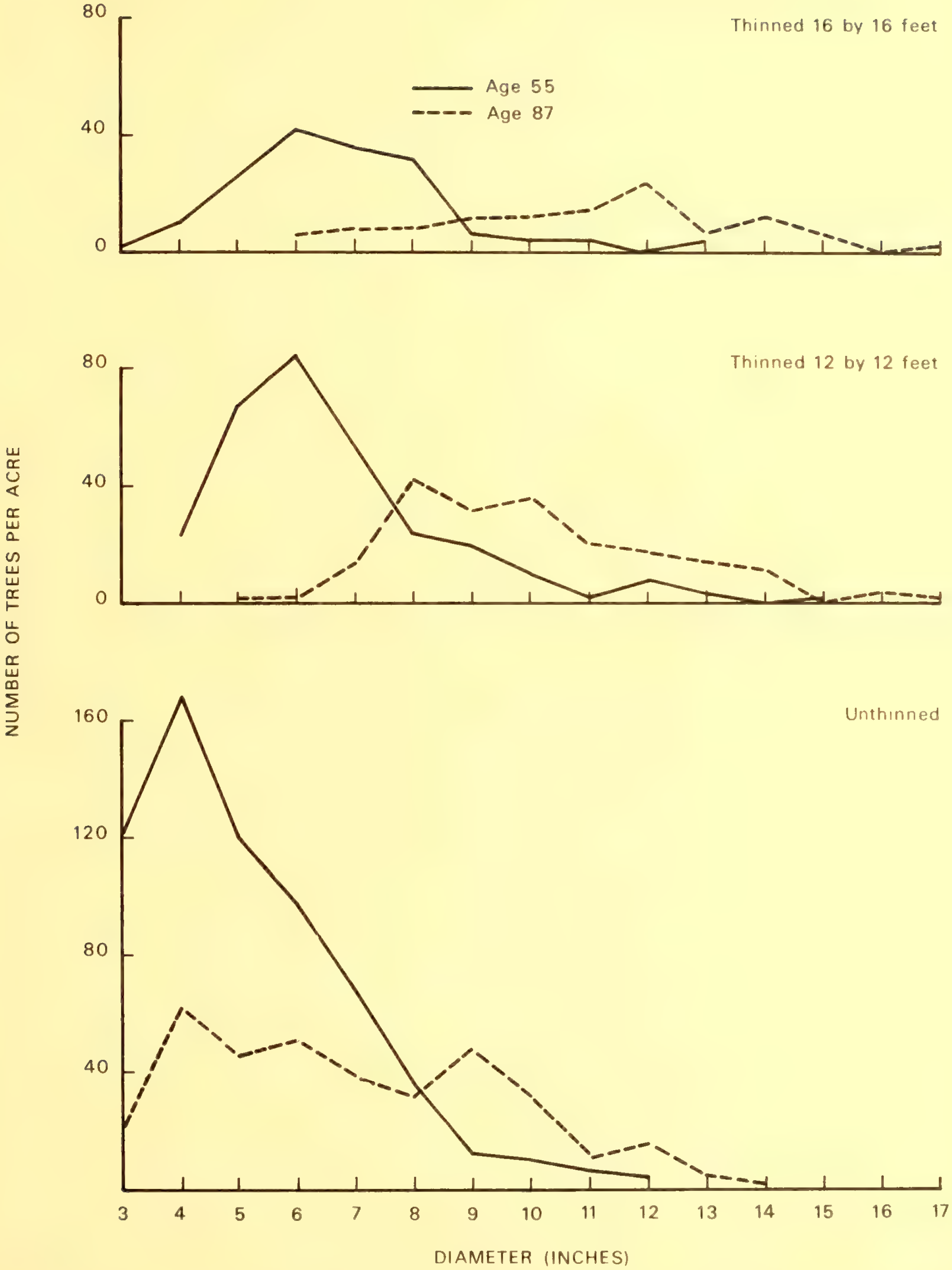

Figure 1.--*Diameter distribution immediately after thinning (age 55) and 32 years later (age 87).*

Table 3.--*Periodic annual gross and net basal area increment--per acre basis--for thinned and unthinned lodgepole pine*

Period	Thinned 16 by 16			Thinned 12 by 12			Unthinned		
	Net	Mortality	Gross	Net	Mortality	Gross	Net	Mortality	Gross
	- - - - - -	- - - - - -	- - - - - -	- - - - - -	*Square feet*	- - - - - -	- - - - - -	- - - - - -	- - - - - -
1935-39	1.748	0.510	2.258	1.986	0.790	2.776	0.050	2.545	2.595
1940-46	.652	1.284	1.936	1.105	1.183	2.288	.231	1.794	2.025
1947-51	1.112	.482	1.594	1.236	.820	2.056	.748	1.259	2.007
1952-56	1.272	.494	1.766	1.041	1.358	2.399	.356	1.953	2.309
1957-61	1.201	.357	1.558	.315	1.224	1.539	.060	1.724	1.784
1962-66	.085	1.018	1.103	1.009	.245	1.254	.132	1.697	1.565
1935-66	.989	.728	1.717	1.115	.952	2.067	.218	1.827	2.045

Thus the thinning probably eliminated many of the trees most likely to die, but because not enough healthy trees were available to leave, substantial mortality continued.

Gross cubic volume increment may not have been greatly affected by thinning for the 32-year period as a whole (table 4). Volume production on the three plots ranked the same as prethinning volume and basal area. Consequently, production differences may primarily reflect prethinning plot differences and some uneven mortality that caused a large hole in the most heavily thinned plot. However, the fact that the plot thinned to 12 by 12 feet produced less than the unthinned plot during the first 5 years but surpassed production on the unthinned area during later periods suggests that thinning probably caused a temporary increment reduction. Although this experiment does not precisely define the relationship of volume increment to stand density, it does indicate that there was no large-scale thinning-caused growth reduction.

Gross cubic volume increment on the unthinned plot was very close to that estimated by the gross volume increment formula from the gross yield table (Dahms 1964). Actual performance was 8.7 percent above that predicted for the 32-year period on the unthinned plot. Because the increment formula was developed from natural stands, a prediction based on the unthinned density was the most meaningful. However, the estimate obtained for the unthinned stand was also close to that for the thinned plots.

Table 4.--*Periodic annual gross and net cubic volume increment--per acre basis--for thinned and unthinned lodgepole pine*

Period	Thinned 16 by 16			Thinned 12 by 12			Unthinned		
	Net	Mortality	Gross[1]	Net	Mortality	Gross[1]	Net	Mortality	Gross[1]
	- - - - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - -	*Cubic feet*	- - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - - -
1935-39	49.0	10.6	59.6	52.7	18.5	71.2	27.0	56.5	83.5
1940-46	27.4	30.9	58.3	39.9	27.9	67.8	23.4	40.8	64.2
1947-51	50.8	10.7	61.5	65.5	21.2	86.7	43.5	31.3	74.8
1952-56	54.6	12.9	67.5	65.6	35.2	100.8	30.6	48.4	79.0
1957-61	51.0	10.8	61.8	31.7	35.6	67.3	19.7	45.2	64.9
1962-66	11.9	31.4	43.3	43.4	6.2	49.6	-5.9	46.4	40.5
1935-66	39.9	18.7	58.6	49.2	24.3	73.5	23.1	44.5	67.6

[1] Includes a small amount of ingrowth.

Net cubic volume increment on the unthinned plot was only about half of that on the thinned plots. About two-thirds of the gross increment was lost to mortality on the unthinned area, compared with only about one-third on the thinned plots.

Net board-foot volume increment ranged from 190 board feet per acre annually on the unthinned plot to 323 on the moderately thinned one (12 by 12 feet) during the 32-year period[4] (table 5). Production averaged about half again as much on the thinned plots as on the unthinned area.

Growth of trees into board-foot size was the big source of increment at first. For example, number of trees with 8.6-inch d.b.h. (present minimum board-foot size) increased from 16 per acre in 1934 to 50 in 1939 on the heavily thinned plot.

Added wood on trees already of board-foot size and an increasing number of board feet per cubic foot with increasing tree size were the principal sources of board-foot increment during the latter part of the 32-year period. The following tabulation of board feet per

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[4] The smallest usable tree on most lodgepole pine sales must produce some studs and is about 8.6-inch d.b.h. This has, been accepted as minimum usable, or board-foot, size for this publication. However, in some instances smaller trees are being chipped, but so far some larger trees must be included to make the operation economically possible.

Table 5.--*Periodic annual gross and net Scribner board-foot volume--per acre basis--for thinned and unthinned lodgepole pine*

Period	Thinned 16 by 16			Thinned 12 by 12			Unthinned		
	Net	Mortality	Gross	Net	Mortality	Gross	Net	Mortality	Gross
	Board feet								
1935-39	270	0	270	148	22	170	113	15	128
1940-46	263	57	320	242	0	242	150	18	168
1947-51	312	35	347	341	41	382	173	57	230
1952-56	399	31	430	507	26	533	173	49	222
1957-61	315	49	364	353	111	464	355	64	419
1962-66	113	145	258	380	0	380	194	84	278
1935-66	278	53	331	323	31	354	190	46	236

cubic foot by tree size illustrates how the more favorable ratio in larger trees can affect board-foot increment:

Tree diameter	*Board feet per cubic foot (1966)*
(Inches)	
9	3.21
10	3.72
11	4.13
12	4.48
13	4.77
14	5.02
15	5.23
16	5.42
17	5.59

Not all trees reached board-foot size. Even on the most heavily thinned plot only 88 out of 110 trees per acre had attained that size by 1966. Unevenly distributed mortality on this plot allowed overly dense groups to develop along with one large hole. Number and percent of total trees reaching board-foot size by treatment are:

Treatment	*Number*	*Percent*
Unthinned	112	31
Thinned 12 by 12 feet	138	70
Thinned 16 by 16 feet	88	80

Net mean annual board-foot increment ranged from 87 board feet per acre on the unthinned plot to 149 on the moderately thinned one at age 87 in 1966 (fig. 2). Because board-foot increment was just beginning at age 55, mean annual increment was low at that time but rising rapidly with increasing age.

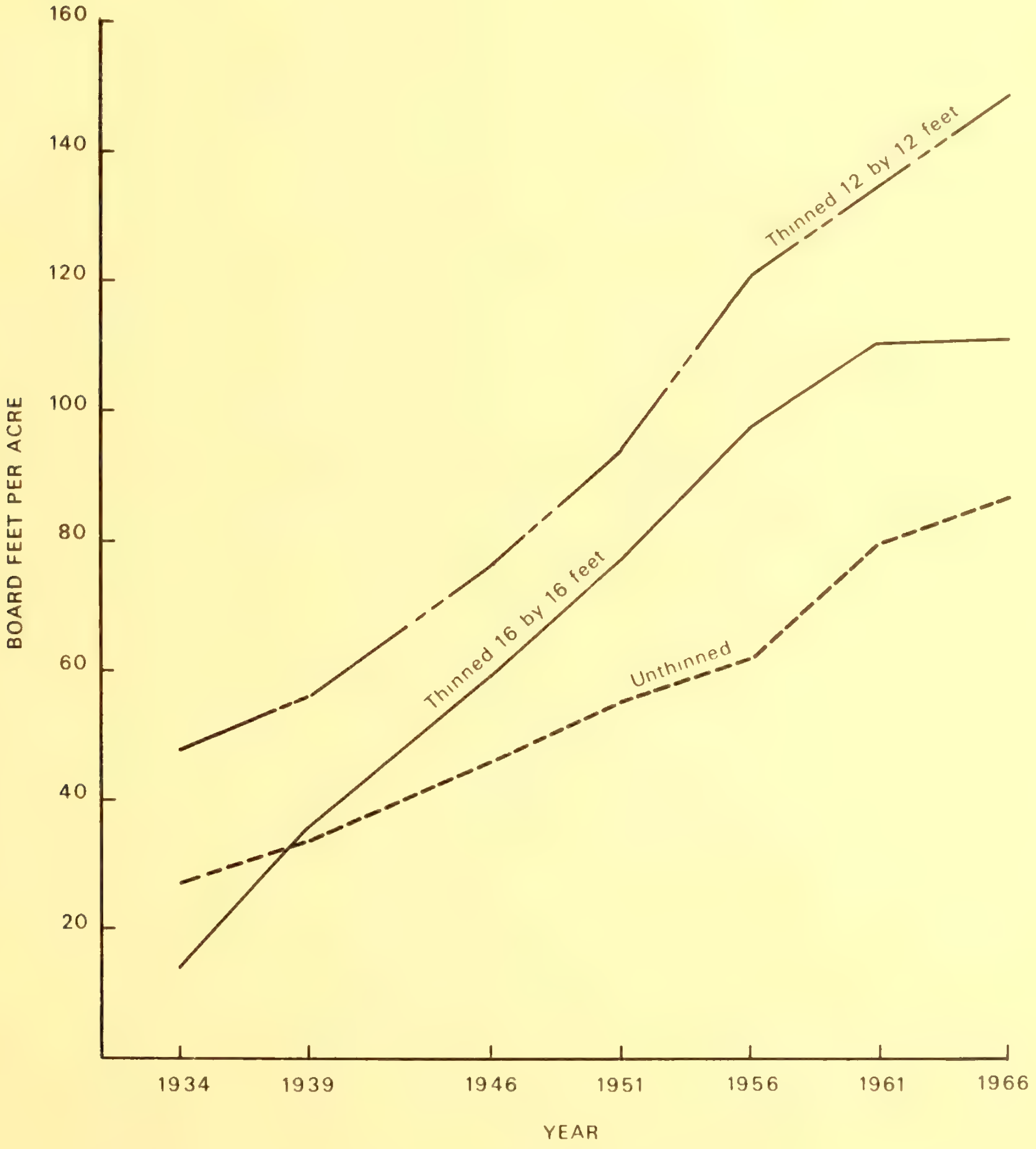

Figure 2.--*Mean annual net board-foot increment--per acre basis--for thinned and unthinned lodgepole pine.*

DISCUSSION

Board-foot, or usable, growth has been substantial during the 32 years after thinning. Net annual per acre volume increment on the two thinned plots averaged 300 board feet for the 32-year period, and mean annual per acre increment reached 130 at age 87. However, slowness of crop trees in reaching board-foot size and heavy mortality losses have dissipated a large portion of the potential usable wood production.

Rust-caused mortality was high on these plots. It accounted for approximately three-fourths of the total volume loss. The large number of infected trees, 67 percent after thinning, was the major reason. Even though this is a much higher than average percentage (Dahms (1965) reported 46.4 percent), wide distribution of cankers in lodgepole pine probably means there usually will be losses.

Thinning the 55-year-old stand achieved rather modest results. Although the apparent percentage increase in diameter growth from thinning was impressive, the advantage in absolute terms was not great. Undoubtedly, a considerable number of trees were "pulled into" the merchantable size class by the thinning. However, the large number of rust cankers and the consequent high mortality and poor vigor of many trees have cut short the growth period and minimized the advantages of thinning.

Net annual increment of approximately 300 board feet per acre during the 32 years after thinning is a positive factor. If a stand as old as 50 or 60 years is too dense to produce a usable harvest but the trees are healthy, a precommercial thinning could provide enough increase in diameter growth to pull a substantial number over the usable size threshold. The present study suggests health of the stand to be thinned is the key consideration in making the thinning decision for older stands.

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USDA FOREST SERVICE RESEARCH NOTE

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SEQUENTIAL SAMPLING OF HEMLOCK SAWFLY EGGS IN SOUTHEAST ALASKA[1]

by

J. S. Hard, *Entomologist*

ABSTRACT

Hemlock sawfly egg population concentrations are classified rapidly through examination of branch samples from the upper crowns of intermediate crown class western hemlock trees selected randomly in sequence. Branch samples are examined only until a single egg is found, which greatly reduces the amount of field time spent examining samples. A tree is called "infested" if the sample yields one or more eggs, and "uninfested" if the sample yields none. Percent of "infested" trees determines egg population concentration. The upper limit for an endemic to light population is 33.3 percent "infested" sample trees. The lower limit for a moderate to heavy population is 50.0 percent "infested" sample trees.

Keywords: *Neodiprion tsugae*, hemlock sawfly, sequential sampling, insect populations.

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[1] The Insect and Disease Control Section under D. Crosby, Region 10, provided funds and manpower for collection of data.

INTRODUCTION

The hemlock sawfly, *Neodiprion tsugae* Midd., is an important defoliator of western hemlock, *Tsuga heterophylla* (Raf.) Sarg., in southeast Alaska. Female sawflies oviposit by inserting eggs singly into the edges of western hemlock needles (fig. 1) in the fall. Usually several eggs comprising a clutch are laid in the needles of a single twig or adjacent twigs before a female moves to another oviposition site. After overwintering in the egg stage, larvae emerge in June. Therefore, the period from October to June provides opportunities for fall or spring sampling to estimate sawfly population levels.

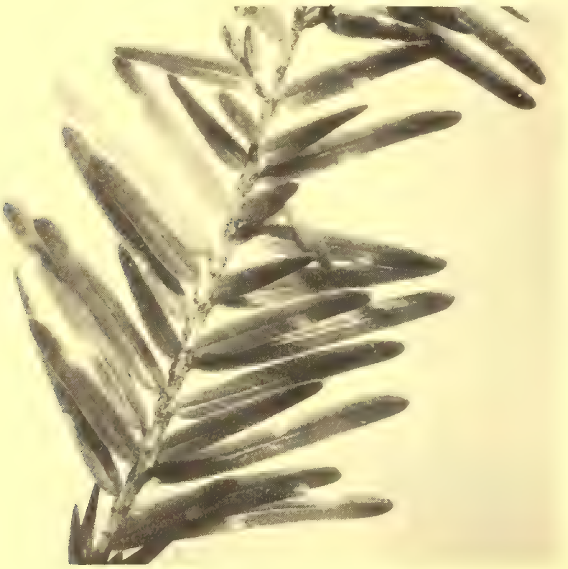

Figure 1.--*Hemlock sawfly eggs in edges of western hemlock needles.*

In the past, population densities were estimated subjectively through a relatively crude system of larval or egg sampling. In order to quickly classify population densities with a known degree of confidence and to enable comparisons of densities between generations, the plan presented here was developed. Its primary purpose is to rapidly determine indices of egg population densities in southeast Alaska. These density classifications do not necessarily imply the same subsequent tree defoliation classifications. They do, however, show which areas could be defoliated significantly provided heavy mortality of young larvae does not occur. Since data for development of the plan were collected widely in southeast Alaska and from a variety of stand conditions, this plan can be used throughout the area.

MATERIALS AND METHODS

A total of 14 locations within nine sawfly infestations (fig. 2) were sampled during April and May of 1967 and 1968. In 1967, 18 hemlock trees were chosen randomly from three stand positions in each of seven infestations. These positions were (1) the fringe of the stand at tidewater, (2) inside the stand, and (3) upslope to the edge of the infestation or to the 500-foot elevation, whichever came first. At each of these three positions six trees were sampled--three intermediate crown class trees and three dominant or codominant crown class trees.[2] The trees were felled, four 36-inch branch tips were removed from the whorl of branches nearest the midpoint of the upper crown half, and four were removed from the midwhorl of the lower crown half. Each branch was taken from a quadrant which contained one of the four cardinal directions when the tree was standing. If a single whorl did not represent all four cardinal directions, branches from adjacent whorls were collected to complete the sample. The branches were labeled and removed to the laboratory where each was divided into a 10-inch distal portion, an 18-inch distal portion, and the remainder. Foliar area and egg counts were recorded separately for each branch portion.

ANALYSIS

The 1967 data were analyzed to determine if significant differences in egg population densities occurred among the various strata. The only significant differences occurred between upper and lower crown levels in areas with high egg populations. Under these conditions, there were significantly more eggs in upper crown samples than in lower crown samples.

Analysis of 1967 data showed a highly significant correlation coefficient of 0.918 between mean numbers of eggs per square foot of foliage from all sampling strata and mean numbers of eggs per 18-inch branch from all trees except those on the fringe at tidewater. Therefore, in 1968, only 12 trees were sampled in each of seven areas (fringe trees were not sampled) and only 18-inch branches were collected for subsequent egg counts. Measurement of foliar area was considered unnecessary because of the strong correlation between egg counts based on foliar area and egg counts per 18-inch branch. Fringe trees were eliminated from the sample because they make up only a small portion of the stand, because their crowns are atypical of crowns within

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[2] *Intermediate*--trees with crowns receiving light from above; tops of crowns generally below level of crown cover but not overtopped.

Codominant--trees with crowns receiving light from above and partially from the sides; tops of crowns composing the general level of crown cover.

Dominant--trees with crowns receiving light from above and from the sides; tops of crowns usually above level of crown cover.

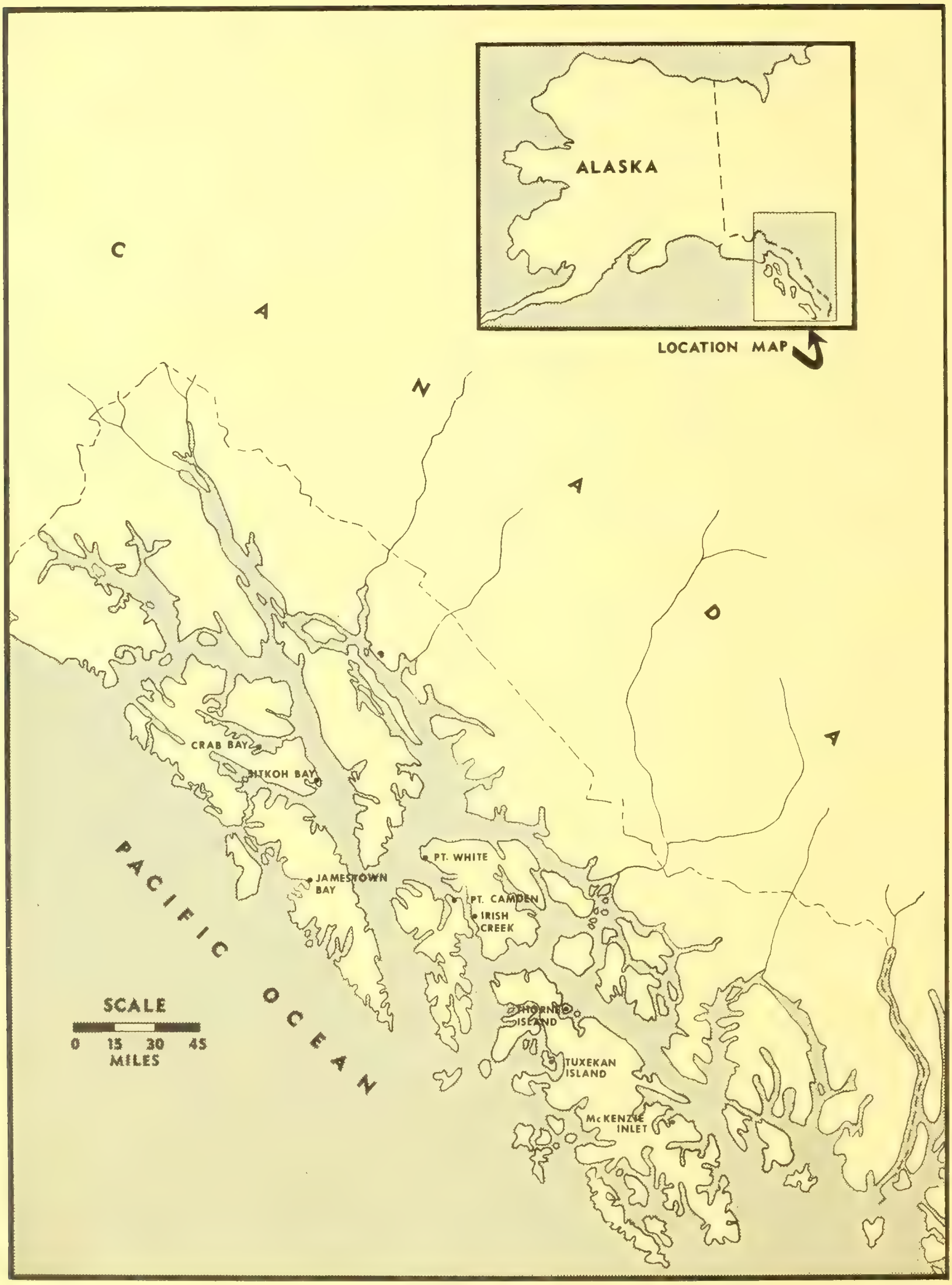


Figure 2.--*Hemlock sawfly infestations sampled in southeast Alaska, 1967 and 1968.*

the stand, and because edge effect and beach-logging of Sitka spruce, *Picea sitchensis* (Bong.) Carr., in the past has resulted in atypical stand composition within fringe areas.

Combined data of 1967 and 1968 showed a highly significant correlation of 0.788 between mean number of eggs per 18-inch branch from all strata and percent of trees that had one or more eggs on upper and lower crown samples. Further analysis showed a highly significant correlation of 0.862 between mean number of eggs per 18-inch branch from all sample strata and percent of intermediate crown class trees only, whose upper crown samples had one or more eggs.

Because egg counting is difficult and time consuming, it was felt that percent of infested trees would give a more rapid estimate of population index. Upper crowns of intermediate crown class trees were chosen as the tree portion to sample because they are not defoliated as heavily as upper crowns of dominant and codominant trees during high population levels, and their egg populations are more closely correlated with overall egg populations within the stands. In addition they are easier to sample and, if felled, result in minimal loss to the stand.

THE SEQUENTIAL PLAN

Many sequential sampling plans use cumulative numbers of insect adults, pupae, larvae, or eggs in making population-index decisions.[3] This plan uses cumulative number of infested trees. It has a major advantage in ease of application over the conventional system in that branch sample units from a single tree are examined only until a single egg is found, and the remainder of the sample is discarded. This saves much time and eliminates the need for making accurate egg counts under the relatively dark, wet conditions that commonly occur in the field in fall and spring.

Class limits for this plan are as follows:

> *Zero to light population.*--Of the sample trees on a plot,[4] 33.3 percent or less bear one or more eggs, which corresponds with an egg population mean of

---

[3] W. E. Waters. Sequential sampling in forest insect surveys. Forest Sci. 1: 68-79. 1955.

[4] A plot consists of a sequential sample of trees from which a single egg population-index decision is made.

approximately two eggs or fewer per 18-inch branch sample from upper and lower crowns of dominant, codominant, and intermediate crown class trees.

Moderate to heavy population.--Of the sample trees on a plot, 50.0 percent or more bear one or more eggs, which corresponds with an egg population mean of approximately five eggs or more per 18-inch branch sample from upper and lower crowns of dominant, codominant and intermediate crown class trees.

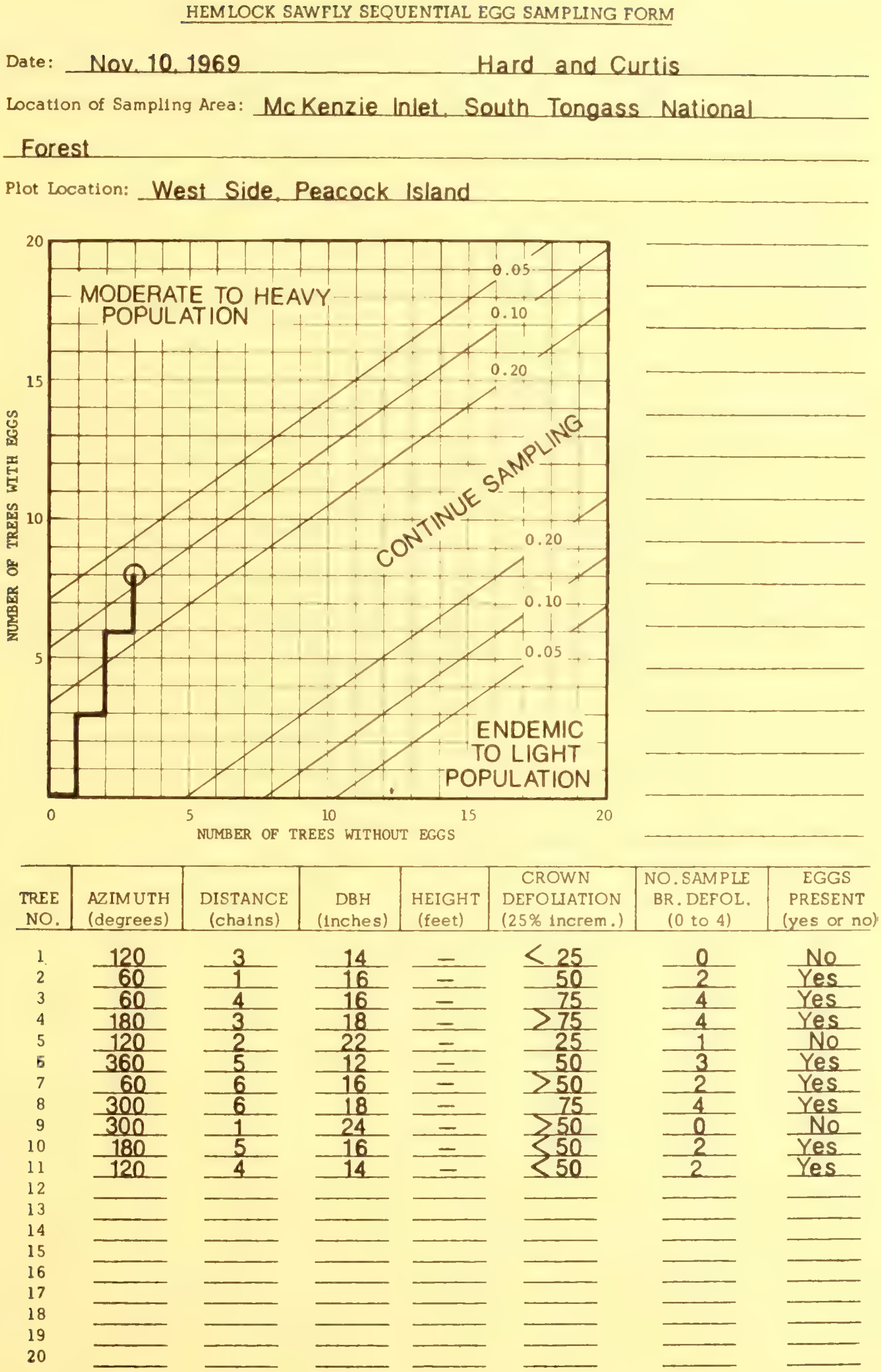
These classes may appear conservative on a mean egg-number-per-branch basis, but the means for upper crowns, where population densities are greatest, are considerably higher than the combined means for upper and lower crown levels shown above.

USE OF THE PLAN

A starting point is chosen at random within a known or suspected sawfly infestation. A die is thrown to determine which direction the sampler will travel to the initial sample point. One represents a 60-degree azimuth; two, 120 degrees; three, 180 degrees; etc. The die is thrown a second time to determine the distance in chains the sampler will travel along the predetermined azimuth. One represents 1 chain, two represents 2 chains, etc.

When the initial sampling point is reached, the nearest intermediate crown class western hemlock tree is climbed or felled, and a sample composed of four 18-inch branch tips is removed from the approximate midpoint of the upper crown. The sample is examined until an egg[5/] is found and then the sample is discarded. The information is recorded on the sampling form (fig. 3). Beginning at the origin of the sequential sampling graph, a line is drawn up one square for an infested tree or right one square for a noninfested tree. The die is thrown again to determine the azimuth and distance to the next sample tree, where the sampling procedure is repeated. Sampling is continued until the penciled trace on the graph crosses one of the decision lines. Using a 10-percent α or β error level, 11 trees were sampled before a "moderate to heavy population" decision was made on the sample form (fig. 3).

[5/] Only eggs laid by females of the most recent generation are to be considered. Although eggs from the penultimate generation may still be found, they can usually be identified by the brown, damaged needle tissue surrounding them and age of needles on which they occur. The sawfly prefers current year's needles for oviposition.



HEMLOCK SAWFLY SEQUENTIAL EGG SAMPLING FORM

Date: Nov. 10, 1969 Hard and Curtis

Location of Sampling Area: McKenzie Inlet, South Tongass National Forest

Plot Location: West Side, Peacock Island

MODERATE TO HEAVY POPULATION
CONTINUE SAMPLING
ENDEMIC TO LIGHT POPULATION
0.05
0.10
0.20
0.20
0.10
0.05
NUMBER OF TREES WITH EGGS
NUMBER OF TREES WITHOUT EGGS
0
5
10
15
20
5
10
15
20

TREE NO.	AZIMUTH (degrees)	DISTANCE (chains)	DBH (inches)	HEIGHT (feet)	CROWN DEFOLIATION (25% increm.)	NO. SAMPLE BR. DEFOL. (0 to 4)	EGGS PRESENT (yes or no)
1.	120	3	14	—	< 25	0	No
2	60	1	16	—	50	2	Yes
3	60	4	16	—	75	4	Yes
4	180	3	18	—	> 75	4	Yes
5	120	2	22	—	25	1	No
6	360	5	12	—	50	3	Yes
7	60	6	16	—	> 50	2	Yes
8	300	6	18	—	75	4	Yes
9	300	1	24	—	> 50	0	No
10	180	5	16	—	< 50	2	Yes
11	120	4	14	—	< 50	2	Yes
12							
13							
14							
15							
16							
17							
18							
19							
20							

Figure 3.--*Hemlock sawfly egg sequential sampling form.*

If the trace had not crossed a decision line, sampling would have been discontinued at 15 trees and the plot called a borderline case. The decision lines are calculated according to specifications given by Dixon and Massey.[6] This equation was used:

$$Y = \frac{\pm Ln\left[\frac{1-\beta}{\alpha}\right] - Ln\left[\frac{1-P_l}{1-P_o}\right] X}{Ln\left(\frac{P_l}{P_o}\right)}$$

where

Y = number of infested trees

X = number of noninfested trees

Ln = natural logarithm

P_o = upper limit to the proportion of infested trees in the infestation class called zero to light (e.g., P_o = 33 percent).

P_l = lower limit to the proportion of infested trees in the infestation class called moderate to heavy (e.g., P_l = 50 percent).

α = probability of calling the population moderate to heavy when the actual proportion of infested trees is P_o (e.g., α = 10 percent).

β = probability of calling the population zero to light when the actual proportion of infested trees is P_l (e.g., β = 10 percent).

Choice of a decision line probability level is made before sampling is begun. The inner decision lines[7] in figure 3 are the least precise since they can be expected to give an incorrect decision one out of five times, but the number of sample trees required is minimal. The outer decision lines[8] are the most precise since they can be expected to give an incorrect decision only one out of 20 times, but the number of sample trees required is greatly increased. The intermediate decision lines,[9] which can be expected to give an incorrect decision one out of 10 times, are adequate for most sampling.

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[6] Wilfred J. Dixon and Frank J. Massey, Jr. Introduction to statistical analysis. 2d ed. New York, McGraw-Hill, Inc., 1957.

[7] $\alpha = \beta =$ 20 percent. $Y = \pm 3.42 + 0.71X$.

[8] $\alpha = \beta =$ 5 percent. $Y = \pm 7.25 + 0.71X$.

[9] $\alpha = \beta =$ 10 percent. $Y = \pm 5.42 + 0.71X$.

Although the graph is essentially a two-level classification, it can be further exploited, as follows: If none of the sample trees bear eggs, the penciled trace on the graph follows the horizontal axis and indicates an endemic population. If all of the sample trees bear eggs, the penciled trace on the graph follows the vertical axis and indicates a heavy population.

Unless the area of the infestation being sampled is relatively small, a single plot will not give an index of population for the entire area. Therefore, an infestation should be broken down into several areas, perhaps determined by degree of defoliation, and one or more sequential samples or plots taken in each. The number of sequential samples taken in an infestation is determined by the sampler's concern for a particular infested stand. The population index for an entire infestation is merely a compilation of the various sample decisions made within the infestation and is represented by the percent of sample plots falling within each class.

Although the data on which this sampling plan is based were gathered in the spring after overwintering egg loss had occurred, the plan can also be used in the fall because overwintering egg loss rarely, if ever, results in loss of an entire egg clutch. Since spring sampling gives little leadtime if results of the sample indicate that control action should be taken in an infestation, fall sampling may be justified in some cases.

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USDA FOREST SERVICE RESEARCH NOTE

PNW-143 February 1971

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CORRELATION BETWEEN DATES OF FLORAL AND VEGETATIVE BUD FLUSH IN DOUGLAS-FIR

by

Frank C. Sorensen and Robert K. Campbell
Principal Plant Geneticists

ABSTRACT

Correlation between dates of floral and vegetative bud flush was nonsignificant for 23 trees. Coefficient of determination was 0.17.

Keywords: Bud burst, *Pseudotsuga menziesii.*

In studying variability in growth and survival of coast Douglas-fir (*Pseudotsuga menziesii* var. *menziesii* (Mirb.) Franco), considerable attention has been given to its phenology (Munger and Morris 1936; Irgens-Moller 1957, 1967; Morris et al. 1957; Silen 1962). Variation of floral development, particularly in connection with sensitivity to spring frosts, has also been noted. Comparing these observations indicated little or no correlation between dates of floral and vegetative bud burst among trees within a single stand. This note reports the results of a study testing the hypothesis of no correlation.

MATERIALS AND METHODS

Twenty-three trees growing on a level area on the west side of the Willamette Valley about 10 miles north of Corvallis, Oreg., were used in the study. The trees were about 25 years old, open grown, and with live crowns extending the lengths of the stems. The observations were made in the spring of 1970.

For bud stage evaluation, five primary branches bearing at least one female floral bud on the most distal secondary twig were chosen and marked. In order to make the observations within the time available, all branches were within 12 feet of the ground and, where possible, were chosen to span the northern half of the lower crown.

Bud stage was observed on *the most distal floral bud* and *the terminal vegetative bud* of each of the five twigs each Tuesday morning and Friday afternoon (that is, each half-week) from the first of March until bud burst was complete. Flushing was considered to have occurred when any green tissue could be seen between the bud scales.

Half-weeks were numbered consecutively from March 10 (the first day flushing was observed on the study trees) as "number 1." Bud burst date for the trees was simply the arithmetic average for the five twigs.

Five observations were available for all trees except one, on which one twig was lost during the course of the observations.

RESULTS

Floral bud burst started at half-week 1 and was concluded at half-week 6; vegetative bud burst started at half-week 16 and was concluded at half-week 21, except for one bud which did not flush until half-week 23. Mean date of floral bud burst (±1 standard deviation) was 4.09 ± 1.36 half-weeks (March 20 ± 4.8 days). Mean date of vegetative bud flush was 18.30 ± 1.41 half weeks (May 9 ± 4.9 days) or 50 days later.

Correlation coefficient (r) between dates of flushing of vegetative and floral buds was 0.411, which just missed significance at 95-percent level of probability. Coefficient of determination (r^2) was 0.17, which means that 17 percent of the variation in either vegetative or floral bud burst is attributable to the linear influence of the other variable. The low level of relationship can be seen in the scatter of points in figure 1.

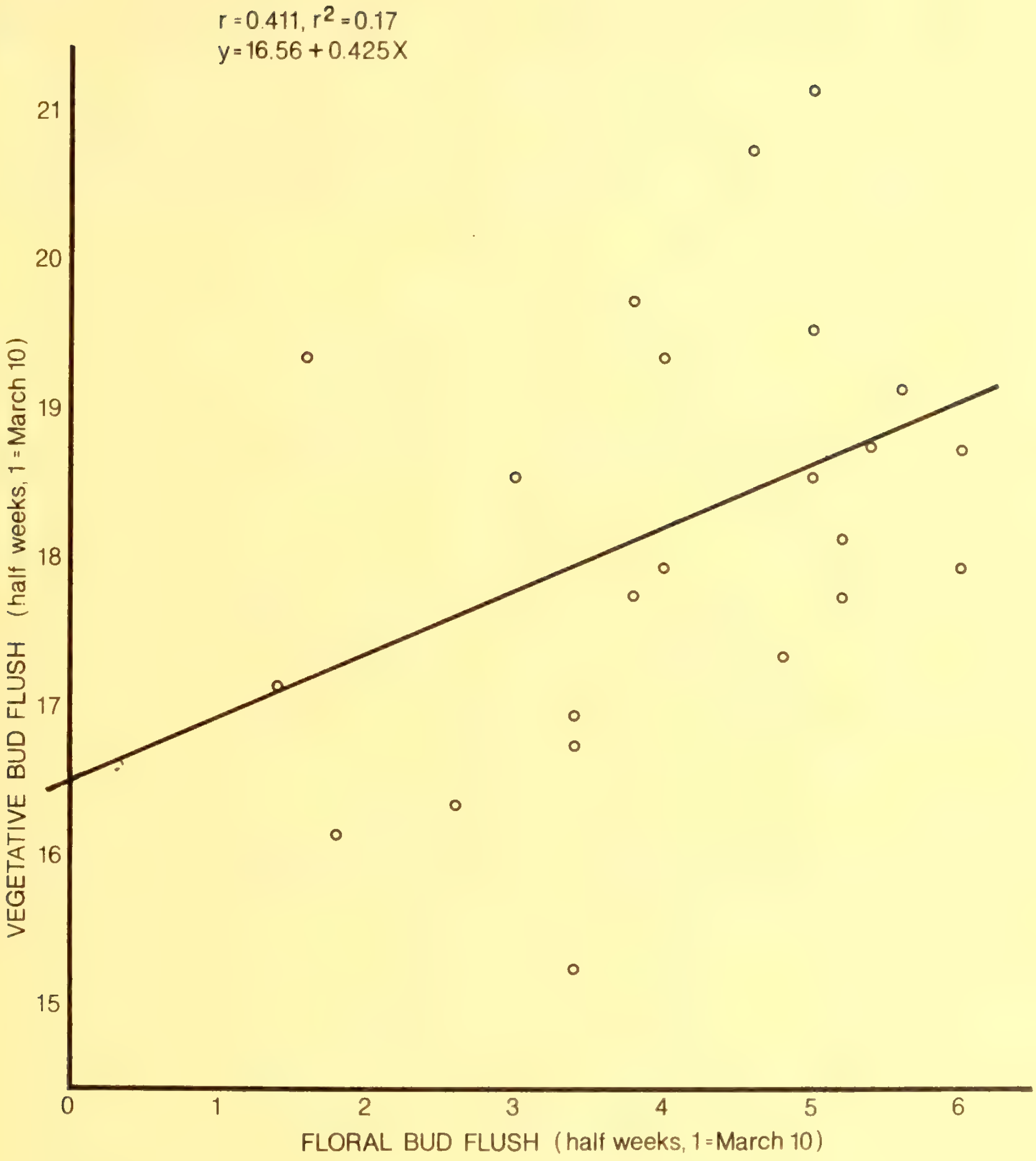

Figure 1.--*Correlation between floral and vegetative bud burst date for 23 Willamette Valley Douglas-firs.*

DISCUSSION

Results from this single population sample indicate little relationship between flushing dates of floral and of vegetative buds. This is similar, in a way, to a previously published report on the lack of correlation between date of floral strobilus receptivity and date of cone maturity among individual trees in longleaf pine (*Pinus palustris* Mill.) (McLemore and Derr 1965). Both of these studies indicate that, although there may be a general underlying mechanism which regulates overall tree phenology to certain climatic events, there still remains much independence in the phenology of the various plant processes. From a practical point of view, this means that as far as rating or ranking trees is concerned, it is not likely to be possible to rank individuals on the basis of phenology of one trait and extrapolate this ranking very accurately to the phenology of other traits.

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USDA FOREST SERVICE RESEARCH NOTE

PNW-144 February 1971

INVASION OF FRESHLY CUT DOUGLAS-FIR STUMPS BY *PORIA WEIRII*

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Earl E. Nelson
Principal Plant Pathologist

ABSTRACT

Poria weirii *spore inoculum failed to penetrate Douglas-fir stumps, but vegetative inoculum of the fungus readily colonized up to 75 percent of stumps, exceeding 12 inches in 1 year in sapwood but slower in heartwood.*

Keywords: Stumps, Douglas-fir, *Poria weirii*, root disease.

INTRODUCTION

Poria weirii (Murr.) Murr. causes a root disease of northwestern conifers much like that caused by *Fomes annosus* (Fr.) Cooke throughout temperate coniferous forests of the world. The two fungi are strikingly similar in vegetative spread and disease symptoms; but, unlike that of *F. annosus*, aerial spread of *P. weirii* by basidiospores has not been considered important in management practice. Wright and Isaac[1] have shown that *P. weirii* can infect trunk wounds on conifers. If stumps can also be infected, even at a low frequency, the already significant *P. weirii* disease problem could be multiplied manyfold by stand thinning. In 1967, we began a continuing study to determine the vulnerability of stumps to invasion by *P. weirii*.

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[1] Ernest Wright and Leo A. Isaac. Decay following logging injury to western hemlock, Sitka spruce, and true firs. U.S. Dep. Agr. Tech. Bull. 1148, 34 p., 1956. Washington, D.C.

METHODS

1967--Spores were collected in the woods on paper beneath *P. weirii* fruiting bodies occurring in unusual abundance that season. Vegetative inoculum was grown aseptically on autoclaved red alder (*Alnus rubra* Bong.) chips in 1-liter beakers for approximately 6 months. The intent was to cut selected trees and inoculate the stumps immediately. However, inoculations were delayed by a woods closure during a period of extreme fire danger when tree falling was not permitted. When rains finally ended the closure, spore discharge from the fruiting bodies had stopped and viability of basidiospores collected earlier was doubtful. Vegetative inoculum, however, remained in excellent condition.

Trees were selected for cutting in a young Douglas-fir stand on the basis of spacing, form, and size. Each tree was rated for crown class and crown condition (i.e., color, needle complement, and general appearance). All selected trees were between 4.2 and 8.3 inches in diameter at 16-inch stump height.

To simplify inoculation of fresh stumps and to assure uniformity of stump surfaces, trees were first felled at 3- to 4-foot stump heights 1 or 2 days prior to inoculation. Immediately before inoculation, stumps were shortened to 16 inches by sawing straight across the diameter with a chain saw to produce uniform, fresh, stump surfaces. Only stumps without obvious stain or decay (105 in all) were used in the study.

Each of five treatments was applied to 21 randomly selected stumps on October 5: (1) spores were applied to the stump surface and the stump covered with heavy, white paper; (2) spores were applied and left uncovered; (3) mycelium in alder chips was applied to the stump surface and covered with paper; (4) mycelium in chips was applied and covered only with cheesecloth; and (5) nothing was applied to stumps (control).

In treatments 1 and 2, approximately 9 million spores in water suspension were applied to each stump. In treatments 3 and 4, about 1 liter of *P. weirii* mycelium in alder chips was spread over the surface of each stump and held in place with cheesecloth. In treatments 1 and 3, stumps were tightly covered with heavy white paper, which in laboratory tests reduced moisture loss by about 50 percent.

Two sheltered hygrothermographs were set at stump height at representative points on the thinned area to measure temperature and humidity. During the following 6 weeks, humidity was generally high, reaching 100 percent most nights. Temperatures varied between 40° and 66° F.

Six, 12, and 18 months after inoculations, the upper 12 inches of seven stumps in each of the five treatments were sawn off, brought into the laboratory, and split down the center. Half of each stump was loosely covered with plastic sheets and incubated in a walk-in cooler at 45° F. Relative humidity in this cooler was not controlled but normally ranges between 90 and 100 percent. After 10 to 14 days, the half-sections were examined for surface growth of *P. weirii* mycelium. From the middle of the other half, a slab 1 inch thick was sawn longitudinally and split aseptically at points one-third and two-thirds of the distance from the pith to the outer edge. Chips taken at 1-inch intervals along the split surfaces were cultured onto malt agar-streptomycin slants.

1968--Inoculations were not made because sporophores did not develop in the woods, probably a result of lower than normal average daily temperatures and much higher than normal precipitation during the study period.

1969--To insure badidiospore inoculum, in midsummer we brought *Poria*-decayed logs into the greenhouse where sporophore formation took place.

Spore inoculum was collected daily on cellophane disks and on petri plates placed beneath the sporophores. Spore viability approached 100 percent. Vegetative inoculum was identical to that described earlier.

Trees were selected and treated in the same manner as in 1967. In all, 85 trees were thinned to provide stumps for the 1969 study. Five of these were inoculated by placing sporophores on a wire rack a few centimeters above each stump surface. The inoculated stumps were then wrapped with heavy paper held around the stump with string. The remaining 80 stumps were randomly assigned to the following four treatments: (1) stumps without inoculation covered with heavy paper (checks), (2) stumps inoculated with spores by placing the cellophane disk inverted on the stump surface and covering the stump with paper, (3) stumps inoculated with spores on a water-agar disk[2] by placing the disk spore side down on the stump surface, and (4) stumps inoculated with chips supporting vegetative hyphae of *P. weirii* and covered with heavy paper. Inoculations were made September 26-28.

Hygrothermograph records again indicated humidity (near 100 percent) and temperature (45°-65° F.) conditions at stump height favorable for germination of basidiospores for nearly 2 weeks following inoculations and for most of the succeeding 2-week period after which records were no longer kept.

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[2] Spores collected on petri plates were covered with cool water agar. When the agar jelled, the disks, with most of the spores on the lower agar surface, were removed.

RESULTS

1967--No stumps inoculated with the doubtfully viable basidiospores contained *P. weirii* at any of the three examination periods, nor did control stumps. However, several of the stumps inoculated with mycelium in alder chips did become colonized with *P. weirii* (table 1). Presence or absence of a paper cover seemed to make no difference under the cool humid conditions that prevailed following inoculations. Stump diameter, crown class, and crown condition of the tree before felling also were unrelated to colonization. Penetration of stumps appeared to be more rapid in sapwood than in heartwood. Other than *P. weirii,* hymenomycetes most often found included: *Stereum sanguinolenteum* (A.&S. ex Fr.) Fr., *Fomes cajanderi* Karst., *Polyporus sericeomollis* Rom., and *P. carbonica* Overh.

1969--Of the 20 stumps inoculated with *P. weirii* in alder chips, 75 percent were colonized at the end of 1 year in contrast to 50 percent after 1 year in 1967. Again, however, none of the spore-inoculated stumps or check stumps were colonized.

Heartwood colonization occurred in only three of these stumps and only to a depth of 4 inches. Sapwood (table 1) was colonized to an average depth of over 7 inches (maximum 12+ inches).

Table 1.--*Invasion of stumps by mycelium of* Poria weirii

Months after inoculation	1967 stumps colonized	Vertical extent[1/]		1969 stumps colonized	Vertical extent[1/]	
		Maximum	Average		Maximum	Average
	Percent	-----*Inches*-----		*Percent*	-----*Inches*-----	
6	71	3	2.3	--	--	--
12	50	12+	9+	75	12+	7+
18	29	6	4.3	--	--	--

[1/] Penetration of stumps by *P. weirii* as measured by culturing chips at 1-inch vertical intervals. Average extent was computed by dividing sum of maximum extents by number of stumps invaded.

CONCLUSIONS

In nature, stumps rarely would be contacted by vegetative inoculum of *P. weirii* in a manner similar to that of this study. Nonetheless, the results demonstrate that:

1. Stumps can be invaded by mycelium of *P. weirii;* whether mycelium from germinating spores will do so remains to be determined.

2. Having gained entry, *P. weirii* mycelia can grow downward at least 12 inches a year--fast enough to enter main roots of thinned tree stumps in a year's time.

3. Growth in sapwood is faster than in heartwood.

4. Under conditions of the 1967 and 1969 experiments, spores of *P. weirii* were not able to infect freshly cut stumps.

We are continuing annual inoculations of stumps and basal wounds to determine the ability of *P. weirii* basidiospores to infect stumps and tree wounds under varied conditions.

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USDA FOREST SERVICE RESEARCH NOTE

PNW-145 March 1971

DWARF MISTLETOE SEED STORAGE BEST AT LOW TEMPERATURE AND HIGH RELATIVE HUMIDITY

by

Donald M. Knutson, *Plant Pathologist*

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ABSTRACT

Dwarf mistletoe (*Arceuthobium campylopodum*) seed survival was determined for seed stored at 16 temperature x relative humidity regimes (-18°, 1°, 4°, 9°, C.; <2-, 6-, 10-, 75-percent relative humidity). Concentrated salt solutions (NaOH, $ZnCl_2$, and NaCl) and (anhydrous $CaSO_4$) were used for the different relative humidities. Germination was tested after 5, 10, and 15 months. The best germination was at 1° C. and 75-percent relative humidity: 94 percent (5 months), 80 percent (10 months), and 58 percent (15 months). Inoculations can now be done throughout the year, facilitating studies of the infection process and mass production of dwarf mistletoe-infected trees needed for outplanting studies.

Keywords: Dwarf mistletoe, *Arceuthobium campylopodum*, seed storage, seed germination.

Year-around inoculation of coniferous hosts with dwarf mistletoe (*Arceuthobium* spp.) seeds[1] requires a dependable method of seed storage. Heretofore, no satisfactory method of year-long storage has been reported for these short-lived seeds.

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[1] The term "seed" is normally used, although members of the Loranthaceae have neither true ovules nor integuments (Kuijt 1960).

Several studies have emphasized the effects of temperature and relative humidity on seed viability and germination. Viability has been determined by the triphenyl tetrazolium chloride technique of Flemion and Poole (1948) as reported by Scharpf and Parmeter (1962) and Wicker (1962), and germination determined by placing surface-sterilized seeds on moist filter paper (Scharpf and Parmeter 1962) or in 1- to 5-percent hydrogen peroxide (Wicker 1962). Viability percent was generally higher than germination percent for *Arceuthobium abietinum* (Engelm.) Hawksw. & Wiens (Scharpf 1970), *A. laricis* (Piper) St. John, *A. campylopodum* Engelm.,[2] and *A. americanum* Nutt. ex Engelm. (Wicker 1965).

Low temperatures (1° to 5° C.) are best for storing dwarf mistletoe seeds 6 months or less (Beckman 1964, Beckman and Roth 1968, Knutson 1969, Wicker 1967). Viability was maintained longer at near freezing than at higher or lower temperatures for seeds of *A. occidentale* Engelm.[3] (Scharpf and Parmeter 1962).

Seed storage experiments for longer periods have been reported. Beckman (1964) found 50- to 56-percent germination of *A. campylopodum* seed after 240 days' storage at 1.5° C. Fifty percent of *A. abietinum* seeds germinated after 200 days' storage at 2° C. (Scharpf 1970). After 12 months' storage at 0° to 5° C., 25 percent of *A. campylopodum* seeds germinated (Wicker 1965).

Relative humidities of 40 to 70 percent maintained *A. campylopodum* seed viability (55 to 65 percent) for 160 days at 1.5° C. Beckman 1964). Above 90-percent relative humidity, fungi destroyed the seeds. Reduced seed germination resulted from storage relative humidities of 75 percent or more when seeds were stored 3 months at 5° C. (Wicker 1965), and fungi destroyed all seeds at saturated relative humidity at 5° C. (Wicker 1967). For short-term storage (62 days at 15° C.) relative humidity had no effect on seed viability (Scharpf 1970).

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[2] Formerly *A. campylopodum* f. *abietinum*, *A. campylopodum* f. *laricis*, and *A. campylopodum* f. *campylopodum*, respectively. Nomenclature changes used in this paper are according to F. G. Hawksworth and D. Wiens. New taxa and nomenclatural changes in *Arceuthobium* (Viscaceae). Brittonia 22: 265-269, 1970.

[3] Formerly *A. campylopodum* f. *campylopodum*.

Materials and Methods

Dwarf mistletoe seeds (*A. campylopodum*) were collected from *Pinus ponderosa* Laws. on the Deschutes National Forest, Oregon, in September 1968. Seeds were harvested by enclosing the mature fruits with a paper bag and shaking the limb to discharge the seeds onto the inner surface of the bag. The bags containing the seeds were placed immediately in a field icebox and stored later the same day at 1° to 2° C. and 100-percent relative humidity until allocated to storage treatments in December 1968.

Storage chambers consisted of 500-milliliter Erlenmeyer flasks with seeds placed on strips (100 per strip) of Scotch Brand Filament Tape.[4] One strip was suspended in each of 16 flasks (fig. 1). Seeds were not surface sterilized or otherwise pretreated. Saturated solutions of NaOH, $ZnCl_2$, and NaCl maintained relative humidity at approximately 6, 10, and 75 percent, respectively. These salts were reported (Winston and Bates 1960) to maintain constant humidity over a wide range of temperatures. Drierite was used to provide relative humidity less than 2 percent. Storage temperatures were maintained at -18°, 1°, 4°, and 9° C. in laboratory refrigerators. Initially

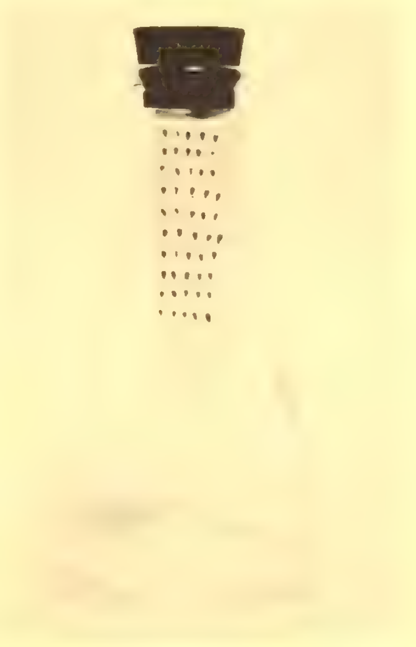

Figure 1.--*Method of storing dwarf mistletoe seed at constant relative humidities.*

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[4] The use of proprietary or brand names does not imply approval by U.S. Department of Agriculture of the product to the exclusion of others which may also be suitable.

and after 5 and 15 months of storage, the relative humidities and temperatures were measured with an electric hygrometer and compared with values summarized by Winston and Bates (1960). Relative humidities in my experiments varied somewhat from values listed for the temperatures used in this study (table 1). Because of possible damage to the electric hygrometer, relative humidities and temperatures at -18° C. were not tested.

Both NaOH and $ZnCl_2$ are deliquescent, which could explain the lower relative humidities at higher temperatures (table 1). As the temperature is raised the amount of solute increases, so the normal situation of rising vapor pressure with rising temperature may be counteracted by a diminution of vapor pressure because of a higher concentration of solution.

Seed germination was determined initially and after 5, 10, and 15 months in storage. Twenty seeds from each of the 16 storage treatments were divided into two lots of 10 and each lot germinated in a petri dish in 15 milliliters of 5-percent H_2O_2 (Wicker 1962). Initial germination (77 percent) was used as a base percent and subsequent data expressed as a percent of this base.

Table 1.--*A comparison of expected and actual relative humidities over three concentrated salt solutions*

Value and temperature	Salt solution		
	NaOH	$ZnCl_2$	NaCl
	---- *Percent relative humidity* ----		
Expected[1/]:			
2, 5, 10° C.	6	10	75
Measured:			
1° C.	11	13	72
4° C.	7	13	74
9° C.	7	6	75

[1/] Winston and Bates 1960.

Results and Discussion

Longevity of dwarf mistletoe seeds was affected by both temperature and relative humidity (fig. 2). Seeds stored at -18° C. did not germinate although the seed appeared normal.

After 5 months' storage, average germination for all relative humidities declined with increasing temperatures (94 percent at 1° C., 65 percent at 4° C., and 60 percent at 9° C.). At 4° C. and 9° C., seed survived best at high relative humidities (fig. 2). In no treatment was the decrease in germination as dramatic as that shown by Beckman (1964) who found that less than 5 percent of the seeds survived after 160 days at relative humidities under 20 percent. Possibly, the sulfuric acid solutions he used to obtain different relative humidities were phytotoxic.

Germination after 10 months' storage at 75-percent relative humidity was 80, 65, and 58 percent for 1°, 4°, and 9° C., respectively. For other relative humidities only seeds stored at 1° C. germinated and, of these, less than 20 percent (fig. 2).

After 15 months' storage, 58-percent germination was obtained at 75-percent relative humidity and 1° C. The only other germination after 15 months' storage was at 75-percent relative humidity and 9° C.

Subsequent to this study, bulk seed batches have retained comparable germinability after 12 months' storage at 1° C. and 75-percent relative humidity. Molds have not been a problem in seeds stored at 75-percent relative humidity, as Beckman (1964) and Wicker (1965) reported them to be on dwarf mistletoe seeds stored at high relative humidities.

Viability of dwarf mistletoe seed can be maintained year-around, providing a source of inoculum for year-around production of infected trees for experimentation.

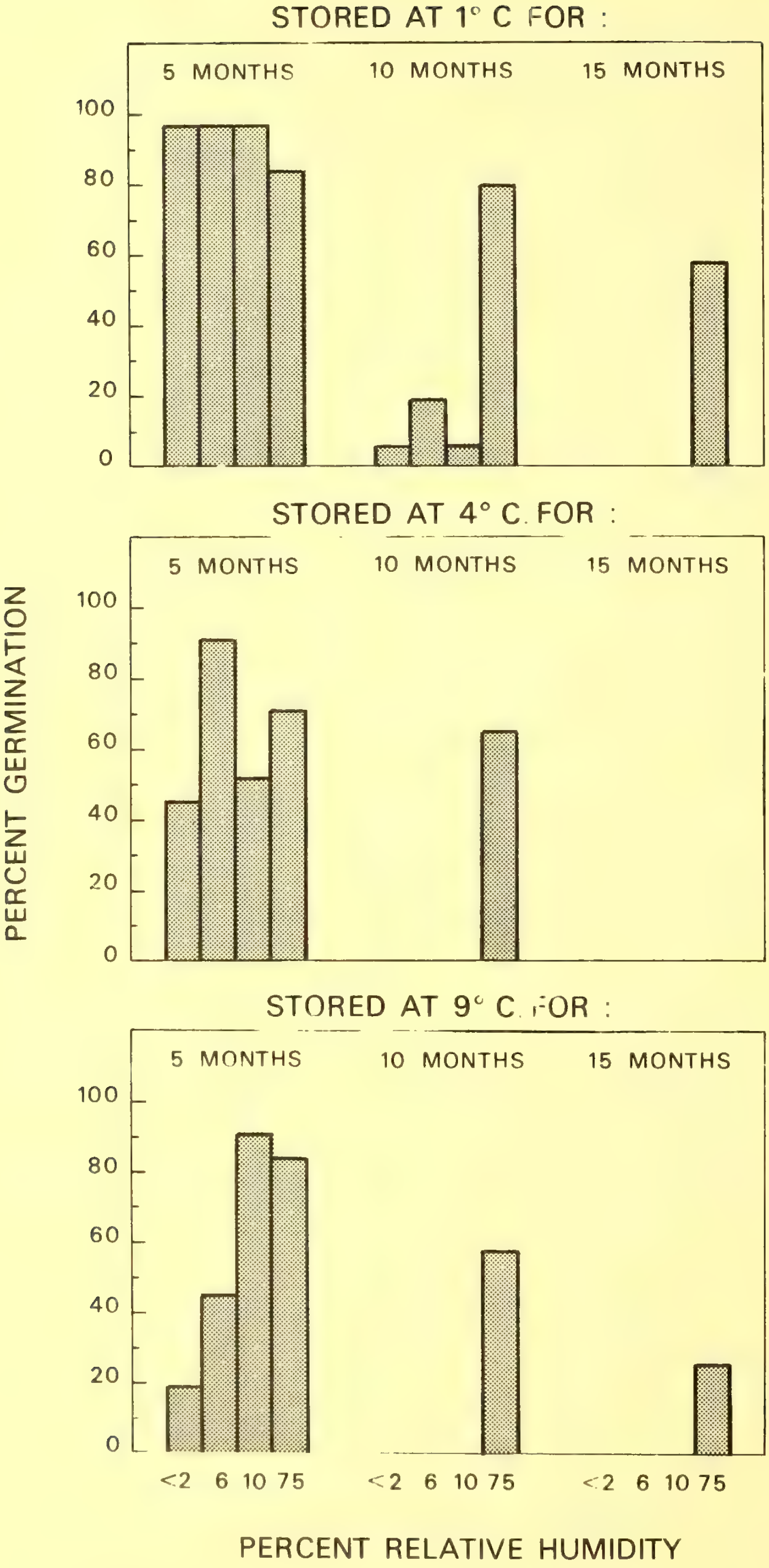

Figure 2.--*Germination*
percent of ponderosa pi
dwarf mistletoe seed fr
36 storage regimes (no
seed germinated from th
18° C. storage regimes)

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USDA FOREST SERVICE RESEARCH NOTE

PNW-146 April 1971

INFLUENCE OF GRAZING AND AGE ON CROWN CHARACTERISTICS IN BITTERBRUSH

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by

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and

Justin G. Smith, *Principal Plant Ecologist*

Abstract

Changes in average crown diameter and percentage of dead crown were related to bitterbrush (Purshia tridentata) *age on moderately and heavily grazed ranges. There was a significant difference in average crown diameter under the two levels of grazing intensity, but the difference between percentages of dead crown area was not significant.*

Keywords: Bitterbrush, plant age, grazing, crown characteristics.

INTRODUCTION

Changes in average crown diameter and percentage of dead crown area are widely used to measure the long-term effects of grazing on bitterbrush shrubs.[1] But information is lacking on the comparative value of these and other indices of plant performance and whether they are sufficiently related to shrub age and intensity of utilization to be of significant management value. Although limited, the following data should interest range and wildlife workers because it questions the effectiveness of these criteria and indicates a need for additional evaluation.

METHODS

A fence-line comparison was made between two bitterbrush populations growing on the same uniform site near Lakeview, Oreg. Except for grazing and grazing-related factors, growing conditions were essentially the same for both study populations, and the effect of location was assumed to be unimportant. Shrubs on one side of the fence had been heavily grazed (80- to 90-percent removal of current twig production) for a prolonged period by cattle--generally during the spring and early summer; and their crowns were low, compact, and tightly hedged. Plants on the other side of the fence had been light to moderately grazed (30- to 50-percent use of current twigs) by cattle for an equally long time during late summer and fall, and their crowns were more open and spreading. All plants were protected from grazing during the growing season when study observations were made.

After field collections were completed,we grouped plants into rough stem-diameter size classes to get representative cross sections of plant ages. Ages were determined by counting growth rings on finely sanded stem sections with a low-power binocular microscope.

RESULTS AND DISCUSSION

The relationships between age of bitterbrush and average crown diameter on the heavily and moderately grazed study areas are presented in figure 1.

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[1] William P. Dasmann. Some deer range survey methods. Calif. Fish and Game Comm. 31(1): 43-52. 1951.

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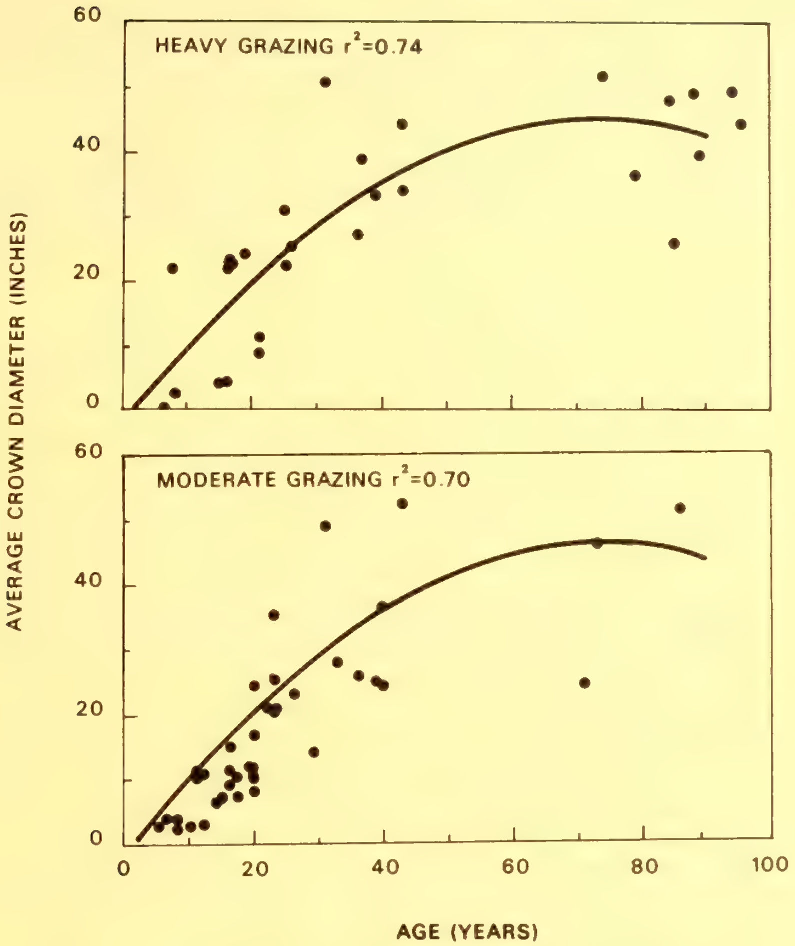

Figure 1.--*Relationship between average crown diameter and age of bitterbrush under moderate and heavy grazing.*

Significant curvilinear regressions were found which indicated that shrub age accounted for about 70 percent of the variation in average crown diameter among moderately grazed shrubs and 74 percent of the total variation in average crown diameter among heavily grazed shrubs. Thus, average crown diameter and age were reasonably related among shrubs receiving a given grazing intensity treatment, but the difference between the crown diameter and age regressions for the two grazing treatments was barely significant at the 0.05 probability level. This suggests that changes in average crown diameter may not be quite as sensitive to changes in grazing as managers often assume.

Figure 2 shows the relationships between age of bitterbrush and percentage of dead crown on heavily and moderately grazed shrubs. As can be

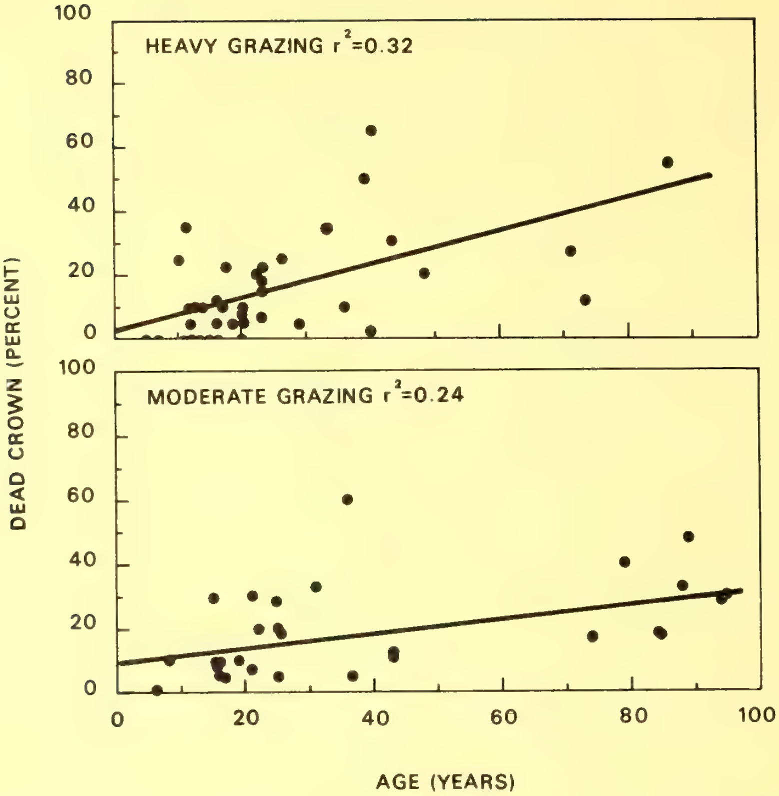

Figure 2.--*Relationship between percentage of dead crown and age of bitterbrush under heavy and moderate grazing.*

seen, weak linear relationships were found which indicated that only 24 percent of the total variation in percentage of dead crown was related to shrub age under moderate grazing compared with 31 percent under heavy grazing. More important, covariance analysis indicated that the two regressions did not differ significantly at the 0.05 probability level. Thus, under the conditions of our study, change in percentage of dead crown was poorly correlated with change in grazing intensity.

As indicated, the results of our study should be of particular interest to range and wildlife managers because they demonstrate the comparative usefulness of these criteria in measuring the response of bitterbrush plants of different ages to different intensities of grazing. We found that neither criterion was entirely satisfactory, but of the two, average shrub crown diameter appeared to have more potential management value. It, too, may have limited value unless sharp differences in grazing intensity are involved. By comparison, changes in percentage of dead crown area appeared to be of questionable management value even when extreme differences in grazing intensity are compared. Additional data are needed, however, before these criteria can be fully evaluated.

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VOLUME TABLES AND EQUATIONS FOR WHITE SPRUCE, BALSAM POPLAR, AND PAPER BIRCH OF THE KUSKOKWIM RIVER VALLEY, ALASKA

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ABSTRACT

Volume tables and equations were derived from a sample of trees from the Kuskokwim River valley. Cubic-foot tables were developed for white spruce, paper birch, and balsam poplar. Board-foot tables, International 1/4-inch and Scribner rules, were prepared for white spruce.

KEYWORDS: Volume tables, volume equations, white spruce, balsam poplar, paper birch, Kuskokwim River valley, Alaska.

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INTRODUCTION

Analysis of data obtained during a preliminary timber reconnaissance in the Kuskokwim River valley in 1966 indicated the volume equations developed by Haack[1] for interior Alaska did not apply to this area. Therefore, in 1967, when an inventory was made of the forest resources along the Kuskokwim River, 295 trees were felled and measured so that volume equations and tables could be developed. Volume equations and tables derived from these measurements are presented here.

The species sampled were white spruce (*Picea glauca* (Moench) Voss), balsam poplar (*Populus balsamifera* L.), and paper birch (*Betula papyrifera* Marsh.). Sample trees were selected by extending the standard forest inventory 10-point cluster[2] to an 11th point. Commercial forest land and operable noncommercial forest land were sampled.[3]

Up to three trees 5-inch diameter breast high (d.b.h.) or larger were systematically selected per point. Cull and obviously deformed trees were not included in the sample

The sample trees were felled and measured using procedures similar to those described by Haack.[4] Diameter outside bark and double bark thickness were recorded at the 1-foot stump, d.b.h., 9.15 feet on the bole, and then at 8.15-foot intervals to a 4.0-inch diameter outside bark. Measurements were also taken where there were pronounced changes in diameter such as at forks. For spruce sawtimber trees, 9-inch d.b.h. or larger, and hardwood species, 11-inch d.b.h. or larger, measurements were also taken at the minimum saw-log diameter, 7-inch and 9-inch diameter outside bark, respectively.

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[1] Paul M. Haack, Jr. Volume tables for trees of interior Alaska. Juneau, USDA Forest Serv. Res. Note NOR-5, 11 p., 1963.

[2] USDA Forest Service, FSH 4813.1 Forest Survey Handbook. p. 42.9--1, March 1967.

[3] Sites capable of producing at least 20 cubic feet per acre per year are classified as commercial forest land by Forest Survey, and sites producing less, noncommercial. Noncommercial sites presently supporting 800 or more cubic feet per acre are considered operable noncommercial.

[4] Paul M. Haack. Compilation of tree measurement data by hand or computer. Juneau, USDA Forest Serv. Northern Forest Exp. Sta., 17 p., 1964.

Smalian's formula was used to compute cubic-foot volume to a 4-inch diameter outside bark.

International 1/4-inch and Scribner rules were used to compute board-foot volumes for white spruce sawtimber trees from a 1-foot stump to a 7.0-inch diameter outside bark for 16.30-foot[5] logs. Partial logs 8.15 feet to 16.30 feet long were treated as full logs. Partial log lengths shorter than 8.15 feet were given zero volume.

These same log rules were used to compute board-foot volumes for birch and poplar sawtimber trees from a 1-foot stump to a 9.0-inch diameter outside bark. Because the sample yielded only 11 birch and 20 poplar sawtimber trees, reliable board-foot volume equations or tables could not be developed. Analysis of the data, however, indicated paper birch in the Kuskokwim River valley has less volume and balsam poplar more volume for a given diameter (D) and total height (H) than reported by Haack[6] for the interior of Alaska in general.

Regression analysis was used to develop the volume (V) equations. Equations tested were:

Weighted combined variable,

$$\frac{V}{D^2H} = \frac{b_0}{D^2H} + \frac{b_1}{DH} + \frac{b_2}{H} + \frac{b_3}{D^2} + b_4 + \frac{b_5}{D^4H}$$

Logarithmic combined variable,

$$\log V = \log b_0 + b_1 \log D^2H + b_2 (\log D^2H)^2$$

and the Schumacher logarithmic equation,

$$\log V = \log b_0 + b_1 \log D + b_2 \log H$$

Separate formulas were developed for each species, location (upper and lower Kuskokwim), and land use (commercial and noncommercial forest land) combination. Subsequent tests using analysis of covariance indicated that data from the upper and lower Kuskokwim and from commercial and noncommercial forest land could be pooled. Analysis of covariance also indicated that cubic-foot volume data for balsam poplar and paper birch could be pooled.

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[5] Includes 0.3-foot trim allowance.

[6] See footnote 1.

Relative efficiency of weighted combined vs. the logarithmic regressions was determined in the manner suggested by Furnival.[7] In all cases, the weighted combined variable equation reduced to the form:

$$\frac{V}{D^2H} = \frac{b_0}{D^2H} + b_4$$

and this form of the equation proved more efficient than either of the logarithmic equations. Schumacher's logarithmic equation was second best in all cases.

The basic data used by Haack[8] to develop volume tables for interior Alaska were compared with these data by use of analysis of covariance. These tests showed a significant difference between equations for all species-volume combinations.

DISCUSSION

These equations and tables were developed for and used with the forest inventory of the Kuskokwim River valley. They may prove superior to other existing tables for use in other timber stands in western Alaska such as the lower Yukon, Koyukuk, and Kobuk River valleys, but no tests have been made to determine this.

The equations used and their precision are given in footnote 1 of each volume table.

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[7] G. M. Furnival. An index for comparing equations used in constructing volume tables. Forest Sci. 7: 337-341, 1961.

[8] See footnote 1.

Table 1.--*Cubic-foot volumes (1-foot stump to 4-inch top, d.o.b.), Smalian's formula, for white spruce, Kuskokwim River valley, Alaska*[1]

D.b.h. (*D*) [2]	Total height in feet (*H*)[3]																	Basis: trees meas-ured[4]
	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	
Inches																		*Number*
5	1.2	1.4	1.7	2.0	2.2	2.5	2.8	3.0										5
6	1.9	2.3	2.6	3.0	3.4	3.8	4.2	4.6										11
7	2.7	3.2	3.7	4.3	4.8	5.3	5.8	6.3	6.9									12
8	3.7	4.3	5.0	5.7	6.4	7.1	7.7	8.4	9.1	9.8								16
9		5.6	6.5	7.3	8.2	9.0	9.9	10.8	11.6	12.5	13.3							18
10		7.0	8.1	9.1	10.2	11.2	12.3	13.4	14.4	15.5	16.5	17.6						14
11		8.6	9.9	11.1	12.4	13.7	15.0	16.3	17.5	18.8	20.1	21.4						15
12			11.8	13.3	14.9	16.4	17.9	19.4	21.0	22.5	24.0	25.5	27.1					14
13			13.9	15.7	17.5	19.3	21.1	22.9	24.7	26.5	28.2	30.0	31.8					11
14			16.2	18.3	20.4	22.4	24.5	26.6	28.7	30.8	32.8	34.9	37.0					8
15				21.1	23.4	25.8	28.2	30.6	33.0	35.4	37.7	40.1	42.5	44.9	47.3			6
16				24.0	26.7	29.4	32.2	34.9	37.6	40.3	43.0	45.7	48.4	51.1	53.9	56.6		11
17					30.2	33.3	36.3	39.4	42.5	45.5	48.6	51.7	54.7	57.8	60.9	63.9	67.0	8
18						37.4	40.8	44.2	47.7	51.1	54.5	58.0	61.4	64.8	68.3	71.7	75.1	6
19						41.7	45.5	49.3	53.2	57.0	60.8	64.6	68.5	72.3	76.1	79.9	83.8	5
20						46.2	50.5	54.7	58.9	63.2	67.4	71.7	75.9	80.1	84.4	88.6	92.9	3
21						51.0	55.7	60.4	65.0	69.7	74.4	79.1	83.7	88.4	93.1	97.7	102	1
22									71.4	76.5	81.7	86.8	91.9	97.1	102	107	112	1
23									78.1	83.7	89.3	94.9	101	106	112	117	123	--
24											97.3	103	109	116	122	128	134	1
25											106	112	119	125	132	139	145	--
26											114	121	129	136	143	150	157	--
27											123	131	139	146	154	162	170	1
28											133	141	149	157	166	174	182	--

[1] Based on weighted regression: $V = -0.40972 + 0.0021198\ D^2H$. Standard error of estimate = 1.37 cubic feet or 5.81 percent of the mean volume.

[2] 10-inch class includes trees 9.6- to 10.5-inch d.b.h.

[3] 70-foot class includes trees 67.6 to 72.5 feet in height.

[4] Number of trees; range of data for 167 trees enclosed by solid lines.

Table 2.--*Board-foot volumes (1-foot stump to 7-inch top, d.o.b.), International 1/4-inch scale, for white spruce, Kuskokwim River valley, Alaska*[1]

D.b.h. (D)[2]	Total height in feet (H)[3]																Basis: trees measured[4]
	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	
Inches																	*Number*
9	11	16	21	26	31	36	41	46	52	57	62						11
10	19	26	32	38	44	51	57	63	69	76	82						14
11	28	36	44	51	59	66	74	82	89	97	104						15
12		48	57	66	75	84	93	102	111	120	129	138					14
13		60	71	81	92	102	113	124	134	145	155	166					11
14		74	86	98	111	123	135	147	160	172	184	196					8
15			102	116	130	145	159	173	187	201	215	229	243	257			6
16			120	136	152	168	184	200	216	232	248	264	280	296	312		11
17				157	175	193	211	229	247	265	283	301	320	338	356	374	8
18					199	219	239	260	280	300	321	341	361	382	402	422	6
19					224	247	270	292	315	337	360	383	405	428	451	473	5
20					251	276	301	326	351	376	402	427	452	477	502	527	3
21					279	307	335	362	390	418	445	473	501	528	556	583	1
22								400	430	461	491	521	552	582	612	643	1
23								440	473	506	539	572	605	638	672	705	--
24								481	517	553	589	625	661	697	733	770	1
25										602	641	680	720	759	798	837	--
26										653	696	738	780	823	865	907	--
27										706	752	798	843	889	935	981	1
28										762	811	860	909	958	1007	1056	--

[1] Based on weighted regression: $V = -24.62022 + 0.0125346\ D^2H$. Standard error of estimate = 21.43 board feet or 12.8 percent of the mean volume.
[2] 10-inch class includes trees 9.6-to 10.5-inch d.b.h.
[3] 70-foot class includes trees 67.6 to 72.5 feet in height.
[4] Number of trees; range of data for 116 trees enclosed by solid lines.

Table 3.--*Board-foot volumes (1-foot stump to 7-inch top, d.o.b.) Scribner scale, for white spruce, Kuskokwin River valley, Alaska*[1]

D.b.h. (D)[2]	Total height in feet (H)[3]																Basis: trees measured[4]
	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	
Inches																	*Number*
9	3	7	12	16	21	26	30	35	39	44	48						11
10	10	16	21	27	33	38	44	49	55	61	66						14
11	19	25	32	39	46	52	59	66	73	79	86						15
12		36	44	52	60	68	76	84	92	100	108	116					14
13		47	56	66	75	84	94	103	113	122	132	141					11
14		59	70	81	92	103	113	124	135	146	157	168					8
15			84	97	109	122	135	147	160	172	185	197	210	222			6
16			100	114	128	143	157	171	186	200	214	228	243	257	271		11
17				133	149	165	181	197	213	229	246	262	278	294	310	326	8
18					170	188	206	224	243	261	279	297	315	333	351	369	6
19					193	213	233	253	274	294	314	334	354	374	394	415	5
20					217	239	262	284	306	329	351	373	396	418	440	462	3
21					242	267	291	316	341	365	390	414	439	464	488	513	1
22								350	377	404	431	458	485	512	539	566	1
23								385	414	444	473	503	532	562	591	621	--
24										486	518	550	582	614	646	679	1
25										529	564	599	634	669	704	739	--
26										575	613	650	688	726	764	801	--
27										622	663	704	744	785	826	867	1
28										671	715	759	803	847	890	934	--

---

[1] Based on weighted regression: $V = -28.74136 + 0.0111643\ D^2H$. Standard error of estimate = 18.21 board feet or 12.7 percent of the mean volume.

[2] 10-inch class includes trees 9.6- to 10.5-inch d.b.h.

[3] 70-foot class includes trees 67.6 to 72.5 feet in height.

[4] Number of trees; range of data for 116 trees enclosed by solid lines.

Table 4.--*Cubic-foot volume (1-foot stump to 4-inch top, d.o.b.) Smalian's formula, for paper birch and balsam poplar, Kuskokwim River valley, Alaska*[1]

D.b.h. (D)[2]	Total height in feet (H)[3]												Basis: trees measured[4]	
	30	35	40	45	50	55	60	65	70	75	80	85	Birch	Poplar
Inches													- - - -*Number*- - -	
5	1.1	1.3	1.6	1.8	2.1	2.3	2.6	2.8	3.1				11	3
6	1.7	2.1	2.5	2.8	3.2	3.5	3.9	4.2	4.6				11	9
7	2.5	3.0	3.5	4.0	4.4	4.9	5.4	5.9	6.4	6.8			8	5
8	3.4	4.0	4.6	5.3	5.9	6.5	7.2	7.8	8.4	9.0	9.7	10.3	13	9
9		5.2	6.0	6.8	7.6	8.4	9.2	10.0	10.8	11.5	12.3	13.1	6	6
10		6.5	7.5	8.5	9.4	10.4	11.4	12.4	13.4	14.3	15.3	16.3	1	10
11			9.1	10.3	11.5	12.7	13.9	15.1	16.2	17.4	18.6	19.8	10	2
12				12.3	13.8	15.2	16.6	18.0	19.4	20.8	22.2	23.6	3	2
13				14.5	16.2	17.9	19.5	21.2	22.8	24.5	26.2	27.8	2	4
14				16.9	18.9	20.8	22.7	24.6	26.5	28.5	30.4	32.3	--	4
15					21.7	23.9	26.1	28.3	30.5	32.7	34.9	37.2	1	1
16					24.7	27.3	29.8	32.3	34.8	37.3	39.8	42.3	1	3
17						30.8	33.7	36.5	39.3	42.2	45.0	47.8	--	2
18							37.8	41.0	44.1	47.3	50.5	53.7	--	1
19							42.1	45.7	49.2	52.8	56.3	59.8	--	--

---

[1] Based on weighted regression: $V = -0.37551 + 0.0019624\ D^2H$. Standard error of estimate =0.98 cubic foot or 9.8 percent of the mean volume.

[2] 10-inch class includes trees 9.6- to 10.5-inch d.b.h.

[3] 70-foot class includes trees 67.6 to 72.5 feet in height.

[4] Number of trees; range of data for 67 paper birch and 61 balsam poplar enclosed by solid lines.

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USDA FOREST SERVICE RESEARCH NOTE

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1971
S. I. TECH. & AGR. DIV.

PNW-148 April 1971

EARLY EFFECTS OF FOREST FIRE ON STREAMFLOW CHARACTERISTICS

by

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Principal Research Forester

ABSTRACT

A comparison of streamflow records from three small mountain streams in north-central Washington before, during, and after a severe forest fire showed three immediate effects of destructive burning. These were:

Flow rate was greatly reduced while the fire was actively burning.

Destruction of vegetation in the riparian zone reduced diurnal oscillation of flow rates.

Flow rates quickly increased to points above protracted normal depletion rates but to varying degrees.

No drastic immediate change in stream temperatures was noted.

Keywords: Forest fire, alteration of flow, riparian water loss, diurnal distribution, evapotranspiration, depletion.

During the early morning hours of August 24, 1970, much of north-central Washington was swept by an intense dry-lightning storm. This heralded the beginning of what would prove to be one of the most serious fire disasters ever to occur in the region. Ultimately about 115,000 acres of timber were devastated in this single lightning-fire sequence. This area included the Entiat Experimental Forest where water yields, climate, and other environmental variables have been

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observed for nearly 10 years on three small watersheds. Study installations were restored and reactivated to extend preburn data into a long-range study of the effects of fire on the environment, and the alteration of these effects by vegetative succession. This paper reports some effects of the forest fire that were immediately noticeable in streamflow characteristics.

STUDY AREA

The Entiat Experimental Forest was set aside in 1957 as a study area representative of much of the forested lands east of the Cascade Crest. It was intended for studies of the integrated hydrologic response to specific forest management practices. Three watersheds--1,168, 1,270, and 1,393 acres in size--were instrumented for study.

The experimental drainages are within the Entiat River basin, an area of generally bold and rugged relief dissected by many tributary streams. Much of the river was occupied by a valley glacier during the Wisconsin stage of the Pleistocene Epoch. As the glacier advanced, downcutting the valley, tributary streams were relatively unaffected. As a result, the study watersheds are hanging valleys above the main valley floor. Elevations range from 1,800 feet at the river to more than 7,000 feet at the headwaters. Mean slope is about 50 percent, but slopes as steep as 90 percent are common. Drainage is generally southwest, with aspects ranging from southeast to northwest.

Base rock is an extensive formation known as the Chelan Batholith, a mesozoic intrusive granodiorite with biotite and hornblende as accessory minerals. A medium to coarse-grained massive rock, the gray granodiorite weathers deeply where exposed. Since the glacial period, most of the area has been overlain by volcanic ash and pumice originating from Glacier Peak volcanism about 12,000 years ago. As amounts of deposition vary, soil depths range from extremely shallow, with numerous rock outcrops, to deposits of unconsolidated material many feet deep. Soils are therefore characterized by loose, poorly developed mixtures of decomposed granodiorite and pumice overlying bedrock.

Prior to the fire, vegetation was almost entirely undisturbed mature forest, with only small areas of subalpine grass-forb and bare rock. About 75 percent of the area was classed as ponderosa pine (*Pinus ponderosa*) saw-log type, with Douglas-fir (*Pseudotsuga menziesii*) as the main associated species. Stocking density ranged from medium to poor, with medium to dense understory of ponderosa pine and Douglas-fir reproduction, snowbrush ceanothus (*Ceanothus velutinus*), bitterbrush (*Purshia tridentata*), pinegrass (*Calamagrostis rubescens*), and numerous forb species.

Climate is typical of the east slope of the Cascade Range (fig. 1). For the period of record available, at 3,000-foot elevation the annual mean temperature is 44.3° F., and average annual precipitation is 18.14 inches. Moisture-laden Pacific storms cross the area mainly during winter. Winters are moderately cold and relatively wet, with precipitation generally occurring as snow from November to May. Summers are warm and dry, with only about 10 percent of annual precipitation occurring from June to September.

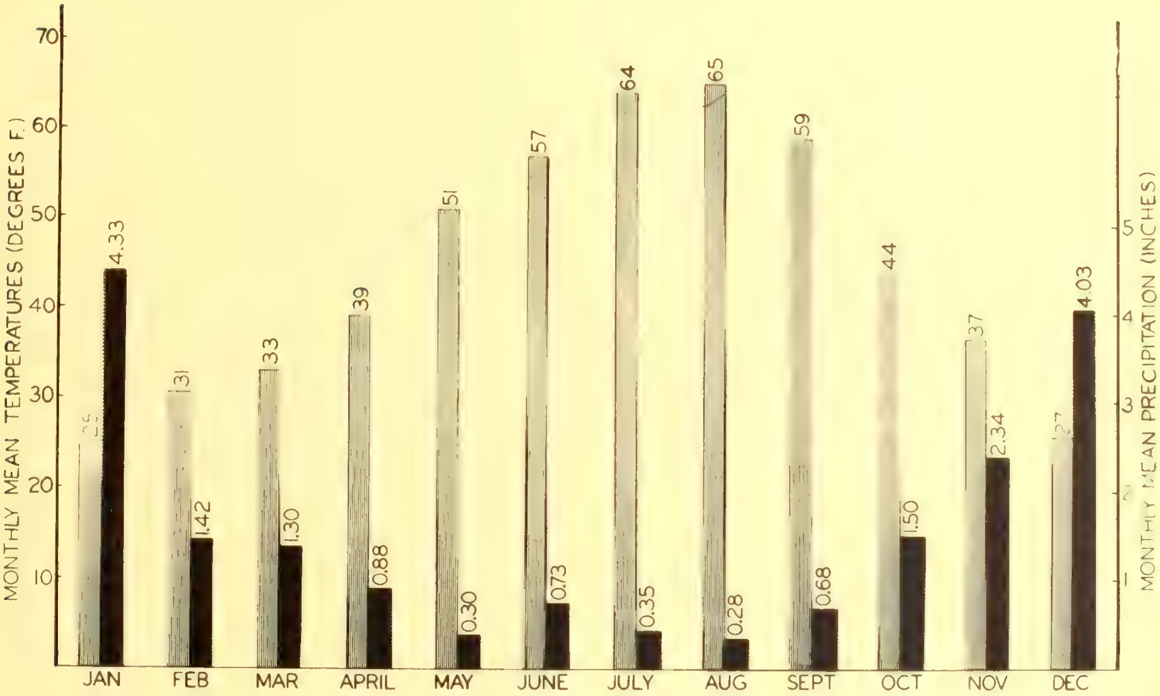

Figure 1.--*Monthly mean temperature and precipitation, Entiat Experimental Forest.*

Streamflow characteristics strongly reflect regional climate (fig. 2). Early winter storms occasionally occur as rain through November. Snow then accumulates throughout the winter, interrupted occasionally by minor melting during brief warm periods. Maximum snowpack is attained in late March or early April. During the spring snowmelt period, streams rise to a peak flow normally occurring in mid-May. Runoff then declines rapidly to a low and fairly steady flow by August or September. Pronounced diurnal fluctuations in runoff rates are evident during the snowmelt season and during summer when evapotranspiration rates are high (fig. 3). During spring snowmelt, maximum daily flow rates occur during the day as a result of maximum insolation. In the summer season, daily minimum flow rates occur during the period of maximum insolation when evapotranspiration is at its peak.

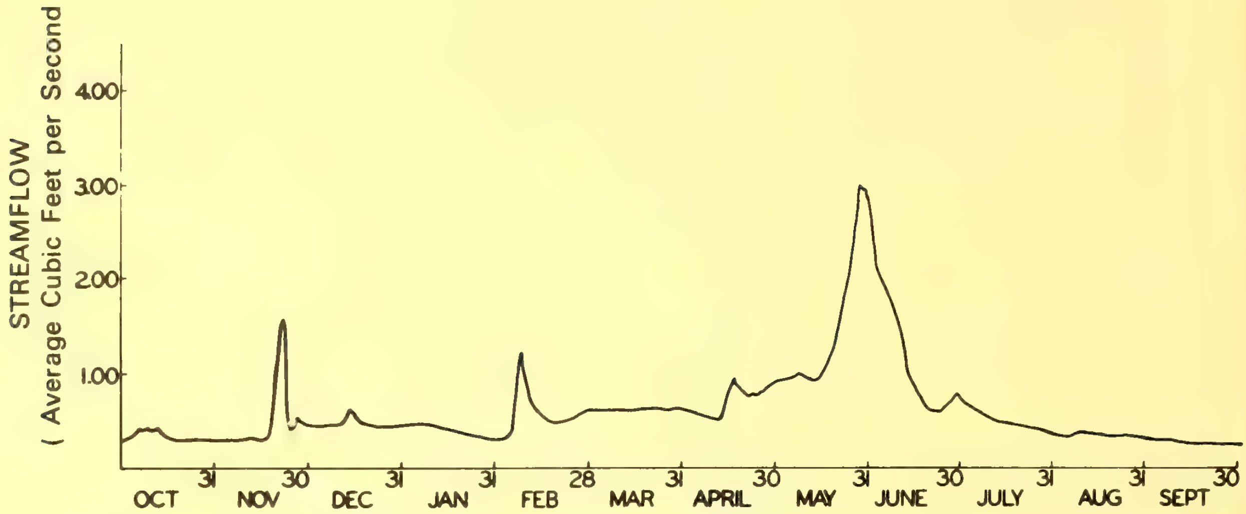

Figure 2.--*McCree Creek streamflow, October 1962 to September 1963, Entiat Experimental Forest.*

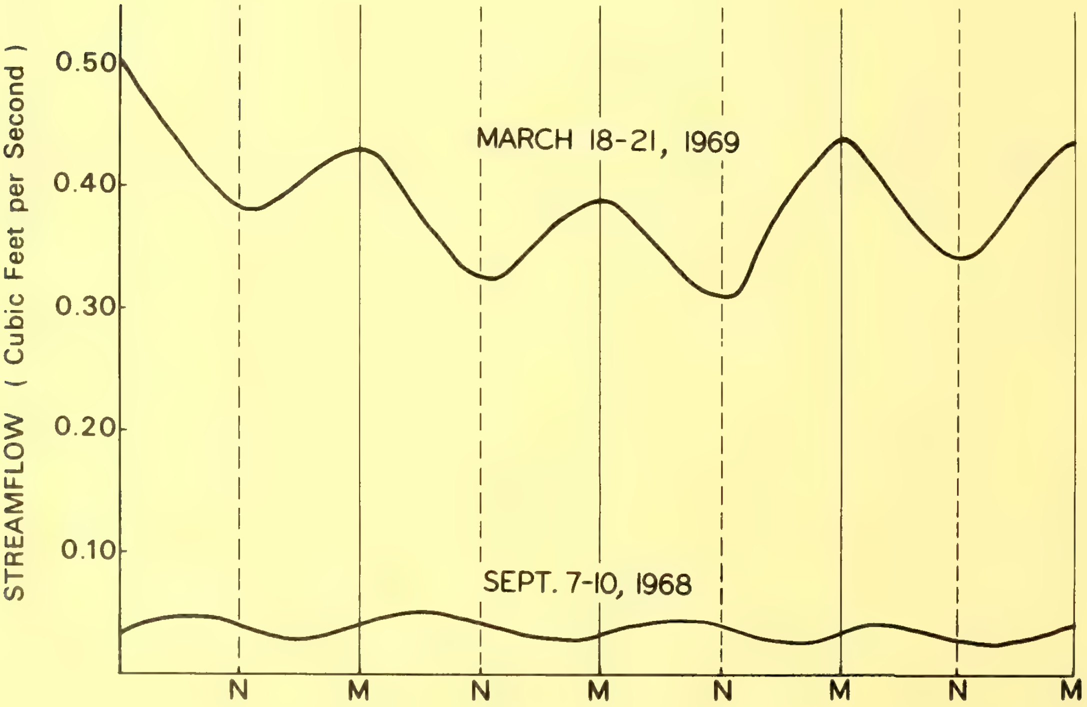

Figure 3.--*Hydrographs showing typical diurnal fluctuations in flow rate during snowmelt period (above) and late summer (below), McCree Creek, Entiat Experiment Forest. N = noon, M = midnight.*

Instrumentation

Streamflow is measured at the outlet of each watershed by continuously recording flow depth over a 120° V-notch sharp-crested weir. Though some icing is experienced for short periods through the winter, the usable record of these installations is essentially year-long. Volume of sediment loss is measured in the weir ponds. Precipitation is sampled along the general centerline of the study area by a recording precipitation gage near 3,000-foot elevation and a non-recording storage-type gage near 7,000-foot elevation. In addition to hydrologic input and output, records of air temperature and relative humidity have been maintained at the 3,000-foot level. Continuous records of stream temperature at all stream gaging stations were begun 2 years prior to the fire.

THE FIRE

A primary factor contributing to the 1970 north-central Washington fire disaster was fuel conditioning by antecedent weather. The period February through August was the driest recorded on the east slope of the Cascades in more than 40 years. During May-August only 0.08 inch of precipitation was recorded on the study area. Daily maximum temperatures in excess of 90° F. were frequent during August, and streamflow was near the seasonal low.

Ignition resulted from a severe lightning storm which formed in southern Washington and spread north and eastward during the early morning of August 24 on a wide and active front. The storm was characterized by hot, multiple strikes and produced essentially no precipitation. A total of 21 lightning fires were set in the Entiat River basin, including three on the Experimental Forest.

As the burning period progressed, efforts of hand crews were overwhelmed. By early afternoon the fast-spreading fronts of several fires began to merge. When the situation became desperate, all vital data and most of the threatened instruments were removed from the study site. Because the risk of the fire's destroying one stream gaging shelter installation (McCree Creek) appeared slight, water level and stream temperature recorders were left in operation at that location.

By 8:00 p.m. the entire Entiat Experimental Forest had been severely and uniformly burned (fig. 4).

Inspection of installations after the fire burned out revealed that the installation where instruments had not been removed was not damaged. Only one of the evacuated installations required major reconstruction. By August 30, instruments had been reinstalled, and extension of preburn data was begun on a plan to evaluate the effects of forest fire and subsequent vegetative succession on hydrologic characteristics.

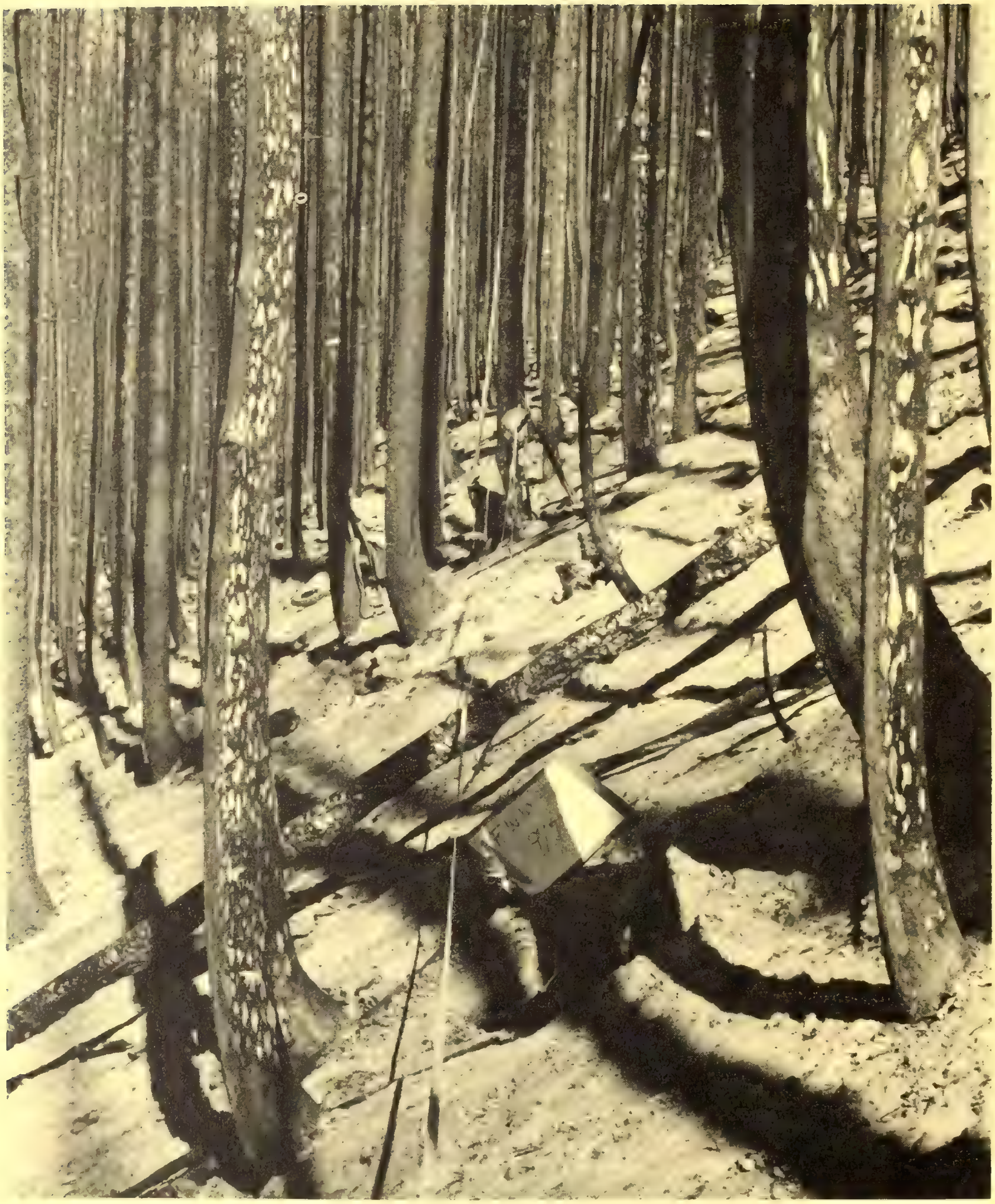

Figure 4.--*View on Fox Creek watershed after the fire. Note that bark burned to the cambium on many stems.*

RESULTS AND DISCUSSION

Hydrographs obtained immediately before and after the forest fire on all three streams are illustrated in figure 5. These reveal several interesting flow phenomena. The most immediate effect on McCree Creek, where continuous instrumentation was maintained, was greatly reduced flow coincident with peak burn intensity and extending into the early morning hours of August 25. This is presumed to be a result of vaporization of water from live stream surface ventilated by strong convection currents.

The manner in which this drainage burned was dramatic. During evacuation of records and instruments, it was observed that McCree Creek was essentially free from fire at about 5:30 p.m. Burns Creek drainage, immediately adjacent to the west, was entirely aflame at that time. At 8:00 p.m. aerial reconnaissance of the general fire area disclosed that fuels over all of McCree Creek were burning fiercely. The timing of this event is reflected in the hydrograph. Flow rate began to drop sharply at the time when daily stream recovery from transpiration loss would normally have begun.

A second and more persistent change in flow characteristics after the fire was the marked reduction of diurnal oscillation in flow rates on all streams.

Streamflow patterns displayed just prior to ignition are striking illustrations of the effects of transpiration by vegetation rooted in the streamside capillary fringe. Because of close correlation with energy availability, transpiration reduces the amount of water entering the channel with daily regularity. The net result is an oscillating flow, characteristic of small headwater or tributary streams in late summer. The forest fire eliminated transpiration draft within the riparian zone of these drainages for the remainder of the 1970 growing season. Only minor daily variations were observed after August 24.

A third change in flow pattern concerned the general elevation of flow rates above extended normal depletion curves.

In the upland areas, beyond the streamside fringe, vegetation derives water from the soil reservoir. There is no nighttime recovery of streamflow from transpiration draft in these zones. Rather, there is a steady decline, or normal depletion, in moisture available for streamflow until recharge by precipitation occurs. Within a week after the fire, flow rates of all three streams were generally above protracted normal depletion curves to some degree. Flows of two streams (Burns and Fox Creeks) were slightly elevated. But the flow of McCree Creek rose sharply for 15 days after the fire to a point considerably higher than normal depletion level. Only a trace of precipitation was recorded until after September 13.

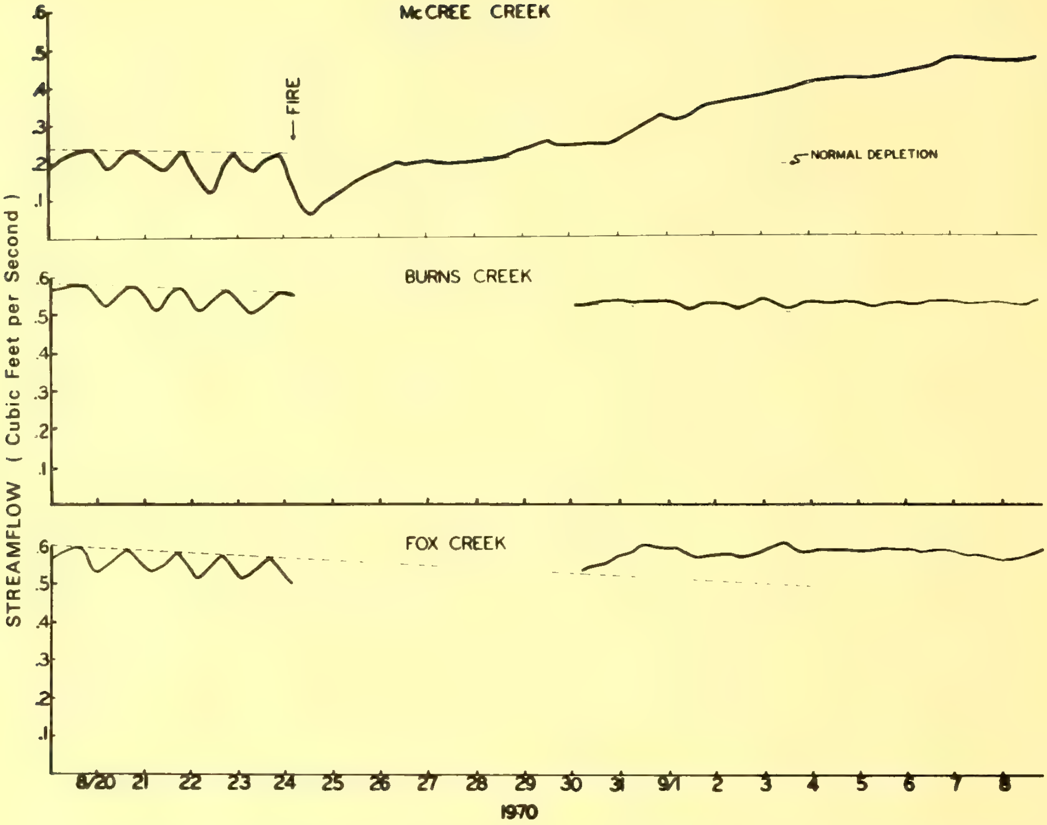

Figure 5.--*Streamflow of the Entiat experimental watersheds, August 20 to September 8, 1970.*

This difference in response may be partly due to prefire differences in vegetative composition. Timber stands on Burns and Fox Creeks were similar in volume and about equally divided between ponderosa pine and Douglas-fir. On the other hand, Douglas-fir comprised nearly 70 percent of the timber on McCree Creek, with 12-percent greater volume. Studies of moisture relations of these species[1] suggest that the Douglas-fir was transpiring more at the time of the fire. Expected release from transpiration draft would therefore be greatest on McCree Creek.

There is some possibility that reduction of evaporation from the soil by a deep ash mulch could have influenced streamflow after the fire. However, evaporation from the soil surface would likely be only a minor component in the daily water balance during late summer.

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[1] William Lopushinsky. Stomatal closure in conifer seedlings in response to leaf moisture stress. Bot. Gaz. 130(4): 258-263, 1969.

Higher flows after the fire may also be an effect of soil heat flux. Moisture migrates from surface layers to lower zones in response to transient thermal gradients produced by the daily temperature cycle.[2] A massive heat flux could be anticipated during the fire and following sudden removal of shade and protective ground cover.

Stream temperatures fluctuated surprisingly little after the fire. The record of McCree Creek water temperature, presented with daily air temperatures in figure 6, shows a brief rise of 1° F. on the third day. Water temperatures then decreased normally as the summer season ended.

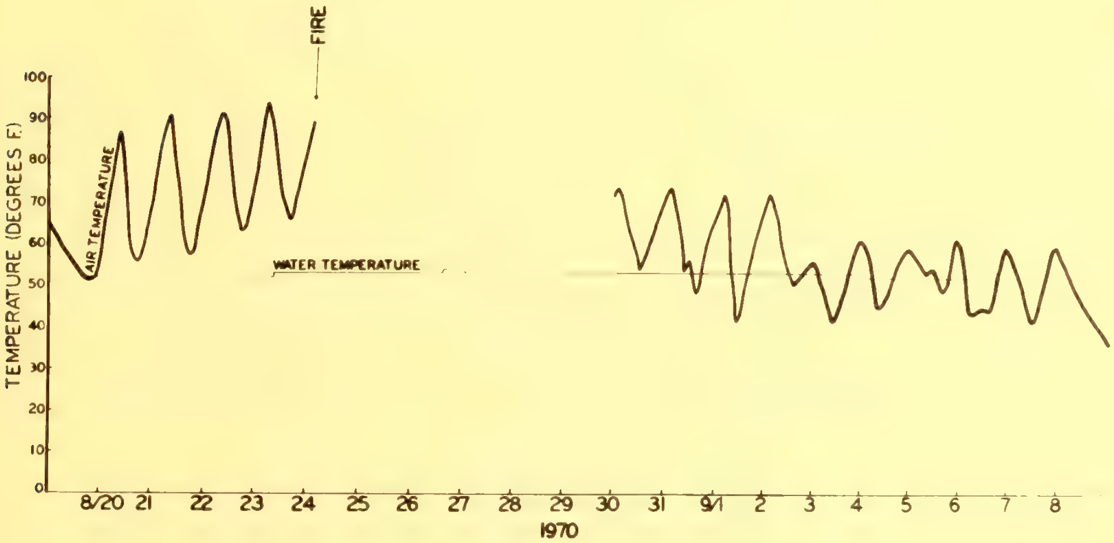

Figure 6.--*Air and water temperatures, McCree Creek, August 20 to September 8, 1970.*

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[2] J. W. Cary. Soil moisture transport due to thermal gradients: Practical aspects. Soil Sci. Soc. Amer. Proc. 30: 428-433, 1966.

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USDA FOREST SERVICE RESEARCH NOTE

PNW-149 May 1971

FROST DAMAGE TO WHITE SPRUCE CONES IN INTERIOR ALASKA

CLEMSON UNIVERSITY
SEP 3 1971
S. L. TECH. & AGR.

by

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Institute of Northern Forestry

ABSTRACT

Cone and seed production is examined for several white spruce (Picea glauca) *stands in Alaska after a late May frost killed or damaged developing conelets. This is the first time frost damage to cone and seed crops has been observed in this subarctic region.*

Keywords: Frost (forest damage), white spruce, cone damage, tree injuries.

During studies of seed production in 1969 in interior Alaska, an exceptionally warm April and May followed by a relatively mild late May frost permitted the observation of some effects of freezing temperatures on cone and seed production. Although this subarctic region is characterized by a relatively cold climate, this was the first observation of frost damage to white spruce cone and seed crops. Frost damage to white spruce conelets in other parts of the species range has been observed (e.g., Cram 1951; Cayford et al. 1959; Waldron;[1/] and Revel[2/]).

[1/] R. M. Waldron. Annual cone crops of white spruce in Saskatchewan and Manitoba 1923-1964. Can. Dep. Forest. Prog. Rep. Proj. MS-158, 34 p., 1965. Unpublished.

[2/] Personal communication with Mr. John Revel, British Columbia Forest Service, Red Rock Nursery, Prince George, B. C.

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METHODS

Cone damage observations and seedfall collections were conducted in five undisturbed stands--Chena River (CR-1), Bonanza Creek (BC-1, BC-2, BC-3), and T-Field (TF)--and in two stands currently being logged--Chena River cutover (CRC) and Rosie Creek (RC). The Chena River stands are river bottom stands and are about 30 miles east of Fairbanks, Alaska (lat. 65° N.). BC-3 is located adjacent to the Tanana River west of Fairbanks. The other stands occur on gently to steeply sloping upland sites west of Fairbanks.

In the undisturbed stands (except TF; see table 1), cones were counted on 15 trees in each area with a variable power spotting scope (15-60 X). These counts were made from one side of the tree only. In the cutover stands, damage estimates were based on cone counts of branches collected from seven felled trees in each area. Only branches which appeared to have no cones broken off as a result of felling were selected. Cones were divided into two categories:

Damaged cones: dead or damaged cones (fig. 1 and 2, A-M)

Apparently undamaged cones: cones not visibly damaged (fig. 2N)

Table 1.--*Estimated number of living and dead and damaged cones per tree in white spruce stands of interior Alaska, 1969*

Area and elevation (feet)		Living cones	Dead and damaged cones per tree	Percent dead and damaged cones
BC-3,	425	110	0	0
TF,	550	(1/)	0	0
CR-1,	650	100	164	62
BC-2,	800	21	40	66
BC-1,	1,250	2	50	96
CRC,	650	240	1,906	89
RC,	750	529	707	57

1/ No cone counts were made in this stand; however, seven trees were intensively sampled throughout the 1969 growing season, and no apparent damage was observed on these or other trees in this stand.

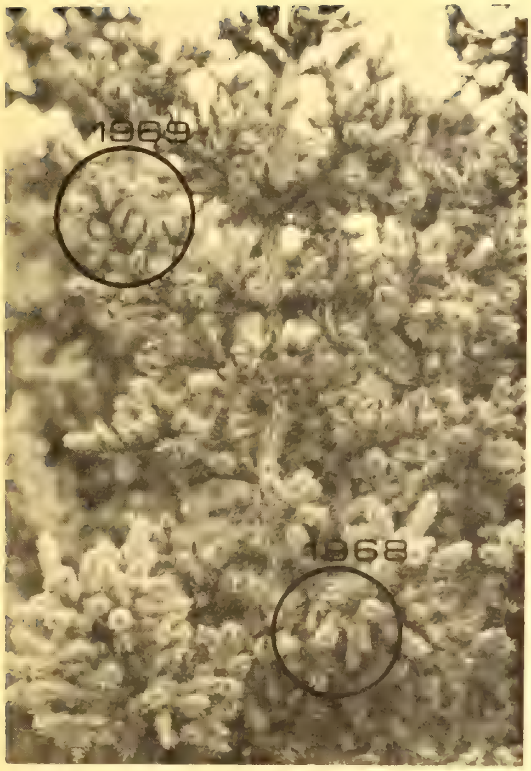

Figure 1.--*Frost-killed conelets, 1969, and undamaged cones, 1968.*

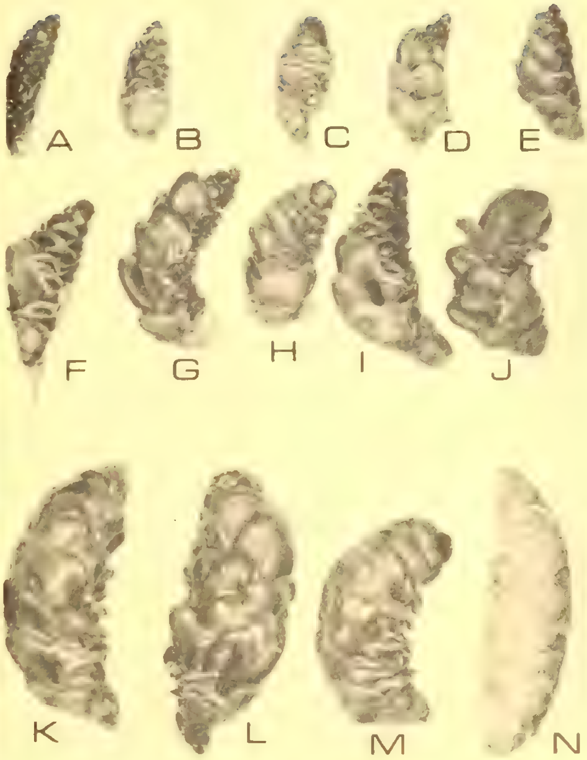

Figure 2.--*Variability in frost damage to white spruce cones. (A--dead cone; N--apparently undamaged cone; other cones have variable number of damaged scales.)*

Cones damaged by frost were collected before seedfall. Seed was extracted from these cones, and germination and cutting tests were conducted on five replicate samples of 100 seeds. Additional information on quality of seed was obtained from seed collected in 10 seed traps in each of the undisturbed stands.

Data on air temperatures were obtained from BC-1, CR-1, TF, and Muskeg[3] field weather stations and from the U.S. Weather Service's (WBFAI, a station located at Fairbanks International Airport) monthly summary of local climatological data for Fairbanks. Thermographs at CR-1 and BC-1 were in instrument shelters 85 feet above ground (this corresponds to the lower to middle portion of the cone-bearing crown). The air temperatures at 85 feet were slightly colder than those recorded on thermographs located at 4.5 feet in these stands. Thermographs at the TF and Muskeg stations were located at 4.5 feet.

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[3] Data provided by R. J. Barney, Forestry Sciences Laboratory, Pacific Northwest Forest & Range Experiment Station, Forest Service, U.S. Department of Agriculture, College, Alaska.

RESULTS

The minimum air temperatures which occurred varied from 25° to 31° F. between the weather stations as did the duration of temperatures below 32° F. (3 to 10 hours) (table 2). These data indicate that, although variable between stands, the frost did occur throughout the Fairbanks area and was not confined to local areas (e.g., frost pockets).

Damage to the cone crop varied between the study stands (table 1), between trees, between cones on the same tree, and between scales on the same cone (fig. 2). Although the cones shown in figure 2 were collected from a number of different trees, there were individual trees with cones in all of these conditions.

Table 2.--*Maximum and minimum temperatures and duration of freezing temperatures for selected weather stations in the vicinity of Fairbanks, Alaska, May 1969*

Area and elevation (feet)	May				
	25	26	27	28	29
	- - - - *Maximum temperatures (° F.)* - - -				
BC-1, 1,250	62	56	45	54	59
CR-1, 650	62	57	44	57	62
TF, 550	65	60	48	58	65
Muskeg, 550	66	60	47	58	65
WBFAI, 433	68	63	50	61	67
	- - - - *Minimum temperatures (° F.)* - - -				
BC-1	48	30	25	33	43
CR-1	42	32	27	36	41
TF	42	35	30	30	34
Muskeg	30	29	28	34	29
WBFAI	48	34	31	36	39
	Duration of freezing temperatures (hours)				
BC-1	0	2	8	0	0
CR-1	0	1	8	0	0
TF	0	0	6	2	0
Muskeg	1	1	5	0	3
WBFAI	0	0	3	0	0

Germination and cutting tests of seed extracted from damaged cones (mostly in the condition represented by fig. 2, K-M) indicated that germination of all seeds (apparent germination) was 13 percent. Sound seed comprised 17 percent of all seed, and of the sound seed, 92 percent germinated (real germination). The amount of sound seed from seeds collected in seed traps varied from 5.9 to 20.2 percent. These values were 20 to 48 percent of comparable 1968 data (table 3).

Table 3.--*Percent of sound seed from seed collected in seed traps in white spruce stands of interior Alaska, 1968 and 1969*

Area	Percent of sound seed[1] [2]	
	1968	1969
TF	38.7 (535)	18.5 (657)
BC-1	42.1 (478)	14.2 (23)
BC-2[3]	45.7 (741)	19.6 (129)
CR-1	30.2 (468)	5.9 (193)
BC-3	--	20.2 (503)

[1] Based on cutting tests performed on all seeds collected from 10 seed traps located in each stand.

[2] Numbers in parentheses are number of seeds examined.

[3] Additional values for this stand are 1957, 62 percent; 1958, 65 percent; 1959, 22 percent.

DISCUSSION

Damage and mortality of cones can be caused by factors other than frost. That this damage was the result of the frost which occurred on May 26 and 27 is based on the following observations. In BC-1 and CR-1, 5 to 7 days after the frost, the affected conelets were observed to be flaccid, turning black, and open-scaled after pollination. The frost occurred during the period of maximum pollen dispersal; thus female flowers in these two stands were probably at a stage of development believed to be most susceptible to mortality caused by frost in other species (e.g., Campbell 1955; Hutchinson and Bramlett 1964; Barras and Norris 1964). In TF, where no visible damage was observed, 60 percent of cones collected on May 26 (16 cones from each of three trees) had closed cone scales and the remaining 40 percent were partially closed and beyond the stage of maximum pollen receptivity. Simak (1969 and in personal communication) reported frost damage of a similar nature to *Larix sibirica* (Ledeb.)[4/] conelets.

In addition to mortality of conelets, the first formed leaves of understory vegetation (particularly *Alnus crispa* (Ait.) Pursh and *A. incana* (L.) Moench subsp. *tenuifolia* (Nutt.) Breitung)[5/] were also killed. Weeden and Roseneau[6/] reported that newly developing alpine flowers in an area near Fairbanks were frozen at this time.

As indicated by the various levels (stand, tree, cone, and cone scale differences) of damage, the effect of this frost was complex. Several factors which may have been important singly or in combination are stand elevation (table 2), duration of freezing temperatures and minimum temperature (table 2), position of cones in the crown, and stage of cone development.

The most important effect of this frost was the great reduction in cones and seeds in some stands. Two other points should also be mentioned. First, even those stands which suffered no apparent damage to cones had a low percentage of filled seed (table 3). Although this reduction could have been caused by insects or disease, cutting of seed and qualitative observations of cones in these stands indicated this was not the case. In view of reports by Andersson (1965), Sarvas (1968), and Simak (1969), it seems possible that the frost could have prevented formation of viable seed in the apparently undamaged cones. Second, cones damaged by frost did produce viable seed, although in much smaller numbers than produced by undamaged cones. Damaged cones did open and disperse seed.

This was the first observation of frost damage to white spruce cone and seed crops in this subarctic region since observations of cones and seed began in 1957 (Zasada and Viereck 1970). On the basis of the infrequency of this phenomenon, frost may not assume great importance. However, when superimposed on the periodicity of seed crops such frosts may have greater importance. For example, observations of cone and seed production indicate that the cone crop in stand CR-1 may have been the best since 1958. If collection of cones had been required in this area or if other silvicultural activities depending on large amounts of seed had been planned, this frost could have had serious consequences.

[4/] B. A. Tikhomirov (1966).

[5/] Hultén (1968).

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PUMICE PARTICLE BRIDGING AND NUTRIENT LEVELS AFFECT LODGEPOLE AND PONDEROSA PINE SEEDLING DEVELOPMENT

by

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ABSTRACT

This was a study to determine if both physical and chemical characteristics of the C1 horizon of the Lapine soil, an Entisol developed on Mazama pumice, limit seedling development. Ponderosa and lodgepole pine seedlings were grown in boxes containing successive layers of soil material from the Lapine A1, AC, C1, and C2 horizons. Bulk density of the C1 horizon was varied by packing, and in half the boxes the C1 chemical composition was changed by nutrient additions. Increased bulk densities reduced rooting depths of both species. Nutrient additions decreased root depth of ponderosa pine but increased root and top weight. Nutrient additions did not significantly affect lodgepole pine size. Results indicate that physical properties of the C1 horizon limit root proliferation. The low bulk density values (0.38 to 0.62 g./cm.^{3}), the high percentage of air-filled pore space (above 20 percent), and the nonplasticity of the pumice material indicate that particle bridging and not bulk density per se is the physical factor limiting root penetration.

Keywords: Soil physics, soil chemistry, root development, soil nutrients, soil bulk density, seedlings, ponderosa pine, lodgepole pine.

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INTRODUCTION

Dyrness and Youngberg[1/] noted that C1 and C2 horizons of the Lapine soil,[2/] a series developed on Mazama pumice, restrict root development of trees and shrubs. Consequently, roots growing in Lapine soils are often concentrated in two different zones: the weathered portion of the Lapine soil (the A1 and AC horizons) and the upper portion of the older soil profile buried beneath the pumice deposit. Dyrness and Youngberg suggest that the low fertility level of the C horizons may be primarily responsible for the restricted root development. Dyrness[3/] points out, in addition, that the physical characteristics of the C horizons may also be important in limiting root development. Will and Stone,[4/] writing about Taupo pumice soils in New Zealand, state that root expansion in some pumice layers is severely restricted because the rough-surfaced, gravel-sized particles bridge together creating a nonyielding structure.

Auger planting of ponderosa pine (*Pinus ponderosa* Laws.) in pumice soils of central Oregon has been effective in recent years, possibly because the auger mixes weathered and unweathered soil material and breaks up the particle bridging. Placement of fertilizer within the planting hole results in an increase in root development within and below the auger hole but very little lateral root development out into the undisturbed C1 horizon.[5/]

Samples taken at a limited number of field locations in south-central Oregon indicate that the bulk density of the coarse Lapine C1 horizon probably varies between 0.4 and 0.6 grams per cubic centimeter (g./cm.^{3}). The fertility of this horizon is low, a fact particularly evident when the nutrient values are expressed in pounds per acre. Total nitrogen is generally below 0.01 percent by weight and the available phosphorus content as determined by the sodium

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[1/] C. T. Dyrness and C. T. Youngberg. Soil-vegetation relationships in the central Oregon pumice region. Proc. 1st N. Amer. Forest Soils Conf., Mich. State Univ., East Lansing, p. 57-66, 1958.

[2/] The Lapine soil is an Entisol having a very dark gray brown (10 YR 3/2 moist) loamy coarse sand or coarse sandy loam A1 horizon approximately 2 inches thick; a yellowish brown (10 YR 5/6 moist) gravelly loam coarse sand AC horizon, 6 to 14 inches thick; a light yellowish brown (10 YR 6/4 moist) medium and coarse pumice gravel C1 horizon, 8 to 20 inches thick, and a light gray (10 YR 7/2 moist) coarse pumice sand and fine pumice gravel C2 horizon, about 14 to 50 inches thick, underlain by the buried soil.

[3/] C. T. Dyrness. Soil-vegetation relationships within the ponderosa pine type in the central Oregon pumice region. Unpublished Ph. D. thesis, Oreg. State Univ., Corvallis, 271 p., 1960.

[4/] G. M. Will and E. L. Stone. Pumice soils as a medium for tree growth. I. Moisture storage capacity. N. Z. J. Forest. 12: 189-199, 1967.

[5/] J. W. Barrett and C. T. Youngberg. Fertilizing planted ponderosa pine on pumice soils. *In* Symp. Ponderosa Pine Regeneration Proc. 1969: 82-88, illus. Oreg. State Univ. Press, Corvallis, 1970.

bicarbonate method is less than 2 parts per million (p. p. m.).[6] Approximately 25 to 37 percent by weight of the C1 horizon consists of gravel-sized particles (greater than 2.0 millimeters), and these particles are bridged together to form a semirigid structure.

Hermann[7] found that ponderosa pine saplings increased growth rates when their roots penetrated the C horizons into the buried soil. He observed that root growth was hindered by the pumice material. He suggested four possible reasons: (1) abrasion of roots caused by movement of the trees due to wind action, (2) mechanical obstruction due to particle bridging, (3) differences in nutrient availability between the pumice layers and the buried profile, and (4) increased availability of water in the buried profile over water in the pumice layers.

The availability of pumice soil water is perplexing. The highly porous C horizons contain water which is held at very low tensions and therefore is available from an energy standpoint. However, poor root proliferation may result in little of this water being available from a positional standpoint. Slow unsaturated flow rates and poor contact between the nonplastic pumice and the root surface may also impede water flow to the root surface.[8] Tigner[9] used a pressure bomb to measure relative water tensions in xylem of mature lodgepole pine growing on Lapine soils with very deep C horizons. In contrast to the above hypothesis, he found that the maximum xylem water stress was never unusually severe even after 2 rainless months and that considerable overnight recovery from stress was maintained. In some of Tigner's study areas, the total depth of the surface A1 plus AC horizons was less than 8 inches and lodgepole roots did not appear to penetrate through the C horizons. If water in the C horizons was relatively unavailable, it is difficult to understand how these trees avoided extremely severe moisture stress.

This study was conducted in a greenhouse to answer the following questions: (1) Do nutrient additions to the C1 horizon increase rooting depths, root weights, and the top weights of lodgepole and ponderosa pine seedlings? (2) Does bulk density of the C1 horizon influence root penetration and seedling weights? (3) Do small ponderosa and lodgepole pine seedlings respond similarly to changes in C1 horizon nutrient levels and bulk densities? Because field conditions are vastly different, extrapolation of results of this study directly to the field is hazardous.

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[6] Assuming a C1 horizon thickness of 16 inches and a bulk density of 0.5 g./cm.^{3} these values are equivalent to 181 lb./acre of total nitrogen and 3.6 lb./acre of available phosphorus within the C1 horizon.

[7] Richard K. Hermann and Roger G. Petersen. Root development and height increment of ponderosa pines in pumice soils of central Oregon. Forest Sci. 15: 226-237, illus., 1969.

[8] P. H. Cochran. Heat and moisture transfer in a pumice soil. Unpublished Ph. D. thesis, Oreg. State Univ., Corvallis, 165 p., 1966.

[9] Timothy Cary Tigner. Resistance to a needle miner in lodgepole pine. Unpublished Ph. D. thesis, Univ. Mich., Ann Arbor, 79 p., 1970.

MATERIALS AND METHODS

Soil materials were placed in 12- by 12- by 18-inch boxes, in layers to duplicate the horizon arrangement of the Lapine profile: 4 inches of C2 horizon material followed by 6 inches of C1, 4 inches of AC, and 2 inches of A1 material for a total soil depth of 16 inches. These soil materials were taken from a pit in the northeast quarter of sec. 1, T. 28 S., R. 10 E., Klamath County, Oregon. A partial physical and chemical analysis of soil from this pit taken from Chichester[10/] is given in table 1. All of the horizons except the C1 were packed to approximately field bulk density.[11/] In six boxes, the C1 material was very lightly packed into the boxes resulting in bulk densities of 0.38 to 0.42 g./cm.^{3}. In six other boxes, the C1 material was solidly packed, resulting in bulk densities ranging from 0.51 to 0.62 g./cm.^{3}.

In three of the boxes from each bulk density range, the C1 horizon was fertilized by thoroughly mixing 600 p.p.m. elemental nitrogen, 300 p.p.m. elemental phosphorus, and 90 p.p.m. elemental sulfur[12/] with the soil before packing. These nutrient levels were estimated to be necessary for maximum top growth by extrapolating response surfaces published by Youngberg and Dyrness.[13/] Commercial ammonium nitrate (34-0-0), treble super phosphate (0-45-0), and gypsum (16.7-percent S) were used as nutrient sources.

To summarize, there were four C1 horizon treatments replicated three times:

(1) Nonfertilized, bulk density 0.51 to 0.57 g./cm.^{3}
(2) Nonfertilized, bulk density 0.38 to 0.42 g./cm.^{3}
(3) Fertilized, bulk density 0.54 to 0.62 g./cm.^{3}
(4) Fertilized, bulk density 0.40 to 0.41 g./cm.^{3} .

[10/] F. W. Chichester. Clay mineralogy and related chemical properties formed on Mazama pumice. Unpublished Ph. D. thesis, Oreg. State Univ., Corvallis, 165 p., 1967.

[11/] Core sampling in the area resulted in field bulk densities of 0.71, 0.76, 0.44, and 0.53 g./cm.^{3} for the A1, AC, C1, and C2 horizons, respectively.

[12/] Using the C1 horizon thickness shown in table 1, and a field bulk density of 0.44 g./cm.^{3}, these nutrient additions are equivalent to field additions of 1,016 lb./acre N, 508 lb./acre P, and 152 lb./acre S.

[13/] C. T. Youngberg and C. T. Dyrness. Biological assay of pumice soil fertility. Soil Sci. Soc. Amer. Proc. 29: 182-187, illus., 1965.

Table 1.--*A partial chemical and physical analysis of the Lapine soil used in this study*[1]

Horizon	Depth	Available P	Total N	Organic matter	>2.0 mm. gravel
	Inches	*Parts per million*	- - - *Percent* - - -		*Percent by weight*
A1	0-2	20.5	0.086	6.97	14.39
AC	2-11	4.5	.041	1.88	16.39
C1	11-28	1.0	.008	.99	33.39
C2	28-53	1.0	.003	.10	25.95

[1] These values were taken from more complete analyses given by F. W. Chichester. Clay minerology and related chemical properties of soils formed on Mazama pumice. Unpublished Ph. D. thesis, Oreg. State Univ., Corvallis. 165 p., 1967.

In each box, eight 1-week-old ponderosa pine seedlings were transplanted alternately with eight 1-week-old lodgepole seedlings at a 2- by 2-inch spacing. The seedlings were grown for 120 days, which allowed the majority to set buds, in a greenhouse under a 15-hour photo period. The average day and night temperatures in the greenhouse were approximately 78° and 65° F.

While the seedlings were growing, the soil was watered to maintain the water content found in the field in early spring. These water contents are approximately 45 percent by weight for the A1 and AC horizons, 90 percent by weight for the C1 horizon, and 60 percent by weight for the C2 horizon. Calculation of the air-filled pore spaces from the bulk densities and the particle density of 2.61 g./cm.^{3} shows that even at a C1 bulk density of 0.62 g./cm.^{3} and a water content of 90 percent by weight, the air-filled pore space is above 20 percent.

During the experiment, no mortality occurred in the high bulk density treatments and only two plants died in the low bulk density treatments. Both were lodgepole pine.

When the experiment was terminated, the side of each box was removed and each plant carefully excavated. Rooting depth, dry weights of tops, and roots and top-root ratios were determined. Plant parts were dried at 90° C. for 2 days before weighing.

STATISTICAL ANALYSIS

Although bulk density is the measured soil physical property in this study, particle bridging is the variable which probably affects root penetration. No measurements of particle bridging are available for pumice soils, and therefore the relationship between particle bridging and bulk density for any given particle size distribution is unknown. As roots penetrate through the C1 horizon, they must either pass through the pore spaces between particles or through the individual particles. If bulk density of C1 material is increased without changing the particle size distribution, the pore space between particles is reduced. When the roots become larger than the pore spaces, the particles must be moved or rearranged and at times, broken. Particle bridging opposes rearrangement and movement of the particles; therefore bridging becomes more limiting at the high bulk densities.

At the start of the experiment, the boxes were randomly placed on a greenhouse bench. The design is a completely randomized split plot with three replications. In addition to the split plot analysis of variance, separate analyses of variance were carried out for each species using a completely random design. Analyses of variance for each species were performed to separate the effects of averaging the two species in the split-plot analysis. Inferences drawn from the separate analyses about individual species are conditioned on the fact that both species were grown together.

RESULTS

Although lateral roots were not counted and measured, it was obvious that the lateral root volume for both species was concentrated in the A1 and AC horizons on all treatments. All ponderosa pine seedlings had taproots which penetrated into, and in some treatments through, the C1 horizon. The lodgepole pine tended to have a taproot system which branched more than the ponderosa root system but penetrated at least into the upper portion of the C1 horizon (table 2).

Additions of nutrients to the C1 horizon decreased the root depth of ponderosa pine but increased the root, top, and total dry weights of this species (tables 2 and 3). Top-root ratios of ponderosa pine tended to be increased by nutrient additions, but this increase was not significant. Nutrient addition alone did not significantly affect root depth, top-root ratios, or the root, top, and total dry weight of lodgepole pine. However, lodgepole pine top weights and ratios of top to root tended to be larger for the fertilized treatments. High bulk densities reduced root depths of both species but did not significantly affect root, top, and total dry weights of either species.

Table 2.--*Average ponderosa and lodgepole pine rooting depths, root weights, top weights, top-root ratios, and total weights for high and low Cl bulk densities with and without nutrient additions*

Treatment		Ponderosa pine					Lodgepole pine				
Cl bulk density	Fertilized?	Rooting depth	Root weight	Top weight	Top-root ratio	Total weight	Rooting depth	Root weight	Top weight	Top-root ratio	Total weight
		Inches	- - *Grams*	- -		*Grams*	*Inches*	- - *Grams*	- -		*Grams*
0.62	Yes	10.2	0.19	0.36	1.90	0.54	7.0	0.07	0.21	3.00	0.28
.59	Yes	8.8	.40	.71	1.78	1.11	7.6	.10	.24	2.40	.34
.54	Yes	11.5	.31	.73	2.36	1.04	7.0	.08	.25	3.12	.33
Average		10.1	.30	.60	2.01	.90	7.2	.08	.23	2.84	.32
.57	No	11.8	.13	.18	1.38	.31	6.9	.03	.08	2.67	.11
.52	No	12.8	.12	.11	.92	.23	6.6	.04	.04	1.00	.08
.51	No	13.0	.20	.35	1.75	.55	7.6	.08	.21	2.63	.29
Average		12.5	.15	.21	1.35	.36	7.0	.05	.11	2.10	.16
.41	Yes	13.3	.21	.41	1.95	.62	8.0	.07	.13	1.86	.20
.40	Yes	13.1	.49	.69	1.41	1.18	9.0	.12	.24	2.00	.36
.40	Yes	12.8	.23	.55	2.39	.78	9.6	.06	.17	2.83	.22
Average		13.1	.31	.55	1.92	.86	8.9	.08	.18	2.23	.26
.42	No	15.5	.13	.18	1.38	.31	8.3	.05	.09	1.80	.14
.41	No	15.4	.21	.35	1.67	.56	12.1	.13	.21	1.62	.33
.38	No	15.4	.19	.42	2.21	.61	10.9	.11	.20	1.82	.31
Average		15.4	.18	.32	1.75	.49	10.4	.10	.17	1.74	.26

Table 3.--*F values for the analyses of variance carried out for each species*

Variable	Ponderosa pine			Lodgepole pine		
	Fertility level	Bulk density	Bulk density x fertilizer	Fertility level	Bulk density	Bulk density x fertilizer
Rooting depth	29.15**	43.78**	0	1.22	16.01**	2.97
Root weight	6.15*	.10	.02	.32	1.84	1.73
Top weight	12.16**	.10	.69	3.34	0	2.25
Top-root ratios	2.99	.41	1.09	3.34	2.07	.15
Total weight	10.39*	.11	.37	2.04	.16	2.04

*Significant at the 95-percent confidence level.
**Significant at the 99-percent confidence level.

Table 4.--*F values for split plot analysis of the measured plant variables*

Variable	F values for split plot analysis						
	Fertility level	Bulk density	Interaction (fertilizer bulk density)	Species	Species x fertility	Species x bulk density	Species x fertility x bulk density
Rooting depth	19.02**	59.71**	1.52	112.90**	3.05	0.19	2.05
Root weight	4.43	.33	.20	50.43**	8.92*	.03	.34
Top weight	10.08*	.06	1.24	61.01**	14.64**	.24	.03
Top-root ratios	3.79	.39	.52	14.52**	.64	6.60*	.24
Total weight	9.58*	.16	.90	43.04**	9.10*	.04	0

*Significant at the 95-percent confidence level.
**Significant at the 99-percent confidence level.

Ponderosa pine seedlings rooted deeper than lodgepole pine and had larger tops and roots, but smaller top-root ratios (tables 2 and 4). This difference in size is not surprising since ponderosa pine seed is about 11 times heavier than lodgepole pine seed and the dry weights of week-old ponderosa seedlings are approximately four times that of week-old lodgepole seedlings. Fertilizer addition tended to reduce the root depths of ponderosa pine more than lodgepole pine, but this difference was not significant. There were differences between species in response of top-root ratios to increasing bulk densities. The average top-root ratio for lodgepole increased with increasing bulk density, with and without fertilizer addition. The average top-root ratio of ponderosa pine decreased with increasing bulk density where no fertilizer was added.

DISCUSSION

Nutrient additions increased the weight of ponderosa pine more than lodgepole pine partly because the ponderosa pine roots penetrated deeper into the fertilized layer which started 6 inches below the surface. The larger root systems of the ponderosa pine were probably able to take up greater quantities of added nutrients during the growing period. This difference between species in response to added nutrients is due, at least in part, to greater initial size of the ponderosa seedlings. However, roots of lodgepole pine may be less able than those of ponderosa to physically penetrate the C1 horizon.

The decreased rooting depth of ponderosa pine with nutrient additions is somewhat surprising. However, Sutton,[14] in a review of factors controlling the form and development of conifer root systems, cites a number of papers in which high fertility levels were associated with a greater number of roots per soil volume, increased root branchiness, and shorter, stubbier roots than were low soil fertility levels. The greater root weights and decreased rooting depths of ponderosa from the fertilized treatments suggest that the photosynthate manufactured by the larger plants was used to enlarge the root system in the zones where nutrients were readily available. In the low bulk density treatments, ponderosa pine taproots barely penetrated the fertilized C1 horizon; while in the nonfertilized treatments, the majority of ponderosa pine taproots penetrated to the bottom of the box. Observations made during removal of the roots indicated that root enlargement with fertilization took place in the A1, AC, and C1 horizons. However, enlargement of the root system seemed to be greatest in the A1 and AC horizons where particle bridging does not impede root proliferation.

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[14] R. F. Sutton. Form and development of conifer root systems. Tech. Commun. No. 7, Commonwealth Forest. Bur., Oxford, Engl., 131 p., illus., 1969.

The decreased rooting depth found in the greenhouse for ponderosa pine with fertilization does not necessarily mean that root penetration through the unweathered C horizons in the field will be slowed by placing fertilizer in the planting hole. Root penetration through the C horizons in the field can take several years.[15] Fertilization produces a plant with larger initial top and root systems, and the larger roots may penetrate the C horizons more rapidly in the years following plant establishment than the roots of smaller nonfertilized plants. Increased withdrawal of C horizon water by enlarged root systems should give the initially fertilized plant an added advantage in the field where water in the surface layers often approaches or exceeds 15 bars tension in late summer.

CONCLUSIONS

Both physical and nutrient characteristics of the C1 horizon may limit seedling development in the field even when water in all soil horizons is held at very low tensions. The low bulk density values, the high percentage of air-filled pore space, and the nonplasticity of the pumice material indicate that particle bridging is the physical factor limiting root penetration. The physical limitation of root penetration suggests that some comparisons between machine and auger planting should be made in the pumice soil region. Possibly auger planting results in more rapid penetration of roots through the unweathered C horizons into the buried soil profile and hence more rapid juvenile growth.

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[15] See footnote 7, page 3.

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INTERSTOCK TRIALS WITH GRAFTED COASTAL DOUGLAS-FIR

by

Donald L. Copes, *Plant Geneticist*

Abstract

Seventeen compatible clones of coastal Douglas-fir were tested as interstocks between incompatible coastal scions and rootstocks. Interstocks did not reduce graft incompatibility between incompatible scion clones and seedling Douglas-fir rootstocks. Only 22 percent of the double-grafted trees had compatible upper and lower unions, whereas 48 percent of the same scion clones were compatible when single-grafted on the rootstocks. A three-way interaction among scion, interstock, and rootstock genotypes may have induced normally compatible scion-interstock combinations to become incompatible.

Keywords: Interstock, grafting, compatibility, incompatibility.

Orchards for production of genetically improved Douglas-fir (*Pseudotsuga menziesii*) seed were established in the Northwest 14 years ago. Rootstocks were grafted because cuttings from adult trees were difficult to root. Scions of adult trees were grafted onto juvenile rootstocks of known geographic source but random parentage. Many clones showed good compatibility, but incompatibility was a serious problem with many others (Copes 1968). Horticulturists have sometimes overcome incompatibility or provided a compatibility bridge in fruit trees by inserting a mutually compatible interstock between the incompatible scion and rootstock (Sax 1953). Little or no improvement in compatibility was achieved in a similar attempt when the Rocky Mountain strain of Douglas-fir from six Western States was tested as an intermediate between coastal Douglas-fir rootstocks and scions (Copes 1970). This paper reports testing of highly compatible Douglas-fir clones of coastal origin as interstocks between highly incompatible scions and seedling rootstocks. It is of particular interest because an unusual form of induced incompatibility at the scion-interstock union was discovered.

METHODS

Seventeen of the most compatible and 15 of the most incompatible clones grafted in western Oregon and Washington seed orchards were used as interstocks and scions, respectively. Selection was based solely on past performance in seed orchards.

In March 1966, eight of the 17 interstocks were grafted in the greenhouse on 200 potted 2-year-old seedling rootstocks of random parentage. Interstocks from each clone were grafted on 25 different rootstocks. One month later, five grafts of each of five scion clones were made on the 25 grafts of each interstock. The basic design used was a factorial of eight interstocks x five test clones grafted with five completely randomized replications of each interstock-test clone combination. Technique losses reduced the number actually tested to about 20 rootstocks per interstock. In addition, the scion clones were single-grafted on the rootstocks. Grafts were grown in the greenhouse the first summer and then placed in a lathhouse for the duration of the study. All the grafts were sacrificed for compatibility tests 18 months after the upper unions were grafted.

Comparable field tests with the remaining nine interstocks and 10 scion clones were installed at two locations in Oregon. Grafting was done in the field on 225 5- to 8-year-old rootstocks using an experimental design similar to that described for greenhouse grafts. Three interstocks and five scion clones were grafted at one location and six interstocks and five scion clones at the other. Interstock clones were grafted in 1965-67, but the scions were not grafted onto the interstocks until 1967-68. In addition, scion clones for three of the interstocks were single-grafted on the rootstocks in 1968. All unions were sacrificed for compatibility tests in the fall of 1968 or 1969.

Compatibility of both field- and greenhouse-grown grafts was estimated by the procedure described by Copes (1967). Sacrificed unions were sectioned with a sliding microtome, stained with safranin 0 and fast green, and then checked for presence of internal incompatibility symptoms (wound-xylem areas). A numerical estimate of average compatibility was obtained from the anatomical observations for each clone (number compatible grafts ÷ number of compatible + incompatible grafts). Interstock grafting was judged successful if the product of the average compatibilities of the upper union times lower union exceeded 70 percent.

RESULTS

The attempt to provide a compatibility bridge between incompatible scions and rootstocks was not successful. The hoped-for gain in compatibility at the scion-interstock union, due to good compatibility of the interstock genotypes, did not occur. Only 30 percent of the scion-interstock unions were compatible (table 1). When compared with single-grafting, double-grafting actually increased the number of incompatible ramets. Only 22 percent (75 x 30) of the double-worked trees were compatible, whereas 48 percent of the same scion clones were compatible when single-grafted on the same rootstocks. The general failure of the interstock method made detailed statistical analysis unnecessary.

Table 1.--*Compatibility of greenhouse- and field-grown grafts at the scion-interstock, interstock-rootstock, and scion-rootstock unions*

Interstock clone number	A, scion-interstock unions	B, interstock-rootstock unions	C, successful double-grafted ramets (AxB)	D, scion-rootstock unions
	- - - - - - - - - - - *Percent*	*compatibility* - - - - - - - - - - -		
Greenhouse:				
10	61	62	38	59
7	46	76	34	53
1	55	74	41	50
5	60	77	46	33
17	50	92	46	56
15	67	74	50	55
26	50	63	31	59
33	50	70	35	40
Average	55	73	40	51
Field:				
65	37	100	37	36
58	0	81	0	40
62	0	71	0	46
163	0	82	0	--
208	0	67	0	--
170	0	68	0	--
167	6	84	5	--
164	24	70	17	--
347	0	62	0	--
Average	7	76	7	41
Total average	30	75	22	48

The difference between greenhouse and field grafts in scion-interstock compatibility, 55 percent vs. 7 percent, respectively, was highly significant (table 1). But the average compatibilities of the scion clones of greenhouse- and field-grown grafts were not significantly different when single-grafted on the rootstocks (51 percent vs. 41 percent, respectively). Therefore, the observed 55 percent vs. 7 percent difference in double-grafts was not primarily due to variation in average compatibilities of the clones tested but to other causes.

There was no correlation found between length of interstock and compatibility of scion-interstock unions in either greenhouse or field trial grafts. Interstocks of greenhouse grafts averaged 4.0 and 4.2 centimeters, and field grafts averaged 21.0 and 18.0 centimeters with compatible and incompatible unions, respectively. Neither difference was significant.

Forty-one percent of the grafts of the scion clones were compatible in the field when single-worked directly onto 5- to 8-year-old rootstocks, yet none was compatible when top-grafted on six of the nine interstocks (table 1). Using 41 percent as the expected proportion of compatible grafts, the probability that just one interstock would, by chance, be incompatible with all five scion clones is about 4 percent. The probability that this should happen six of nine times by chance is very low. An induced form of incompatibility is likely the cause of this phenomenon. Induced incompatibility refers to the condition where normally compatible graft combinations are made incompatible by factors or conditions other than the two adjacent graft components themselves. Lack of good compatibility at the upper union did not adversely affect the proportion of compatible interstock-rootstock unions (75 percent) nor the scion-rootstock unions (48 percent).

A side observation of theoretical importance was made. Past work with single-worked Douglas-fir ramets has shown uniformity in compatibility response within grafts of the same scion-rootstock combinations when grown under the same environmental conditions (unpublished data). For example, if grafts of one scion are made on five different branches of one rootstock, the five unions are either all compatible or all incompatible. Grafting scions of a given clone on an interstock should also have resulted in similar uniformity, but this did not occur within many of the combinations that had some compatible grafts. For example, two compatible and three incompatible unions were found in the five grafts of clone 2 top-grafted on interstock 10. This may be the same induced reaction noted in the field-grown grafts where six of nine interstocks were incompatible with all five scion clones, except the reaction was not as severe in the greenhouse. Only part of the grafts of each scion-interstock combination was made incompatible, whereas field grafting appeared to increase this induced incompatibility. A simple explanation of the induced incompatibility within the scion-interstock combinations was not evident because, surprisingly, no correlation was found between the compatibility of the three unions: scion-interstock, interstock-rootstock, and scion-rootstock.

DISCUSSION

Successful interstock grafting requires good compatibility at both upper and lower unions. For a particular interstock, seven of 10 scion-interstock unions and all of the interstock-rootstock unions would have to be compatible if 70 percent (70 x 100) success was to be obtained. Even better compatibility would be required at the upper unions if some lower unions were incompatible. Actually, only 30 percent of the upper unions and 75 percent of the lower unions in this study were compatible; thus only 22 percent (30 x 75) of the double-worked ramets were compatible. The best interstock tested, interstock 15, was only 50 percent successful when double-grafted. If this method is to be successful in Douglas-fir, a widely compatible interstock is needed, such as the Old Home variety in pears (Hansen and Eggers 1951).

Although interstocks failed to improve compatibility of Douglas-fir grafts, an unusual form of induced incompatibility was suggested. The data indicate that interaction between scion-interstock-rootstock genotypes may have caused compatible combinations of scion-interstock to become incompatible. This was evident in field-grown grafts where six interstocks were totally incompatible with all five scion clones, and was further evident in many of the remaining scion-interstock combinations where lack of uniformity in compatibility was observed. This occurrence was highly divergent from the expected behavior. Cited examples of induced incompatibility are rare, but two similar examples were reported for double-grafts of peach-plum (Mosse 1960) and apples (Luckwill 1958).

In Douglas-fir, it appears that three genotypes must be arranged in a linear sequence before incompatibility is induced at the scion-interstock union. It is speculated that rootstock genotypes produce substances which are made toxic to cells of the scion-interstock unions during passage through the interstock tissues. Basipetal movement of the factor responsible for induced incompatibility probably does not occur since no apparent increase in incompatibility was noted at the interstock-rootstock unions. Prior to this study, all incompatibility symptoms in Douglas-fir seemed to fit the "localized type" described by Mosse (1962). As now demonstrated in double-grafted trees, the presence of the "translocated type" is also a possibility.

The causes of lower compatibility at the scion-interstock unions in field- vs. greenhouse-grown grafts are not known. Potential causes are differences in rootstock age, interstock length, time interval between grafting the upper and lower unions, or original environment. But since interstock length had no effect on compatibility within field-grown grafts, it seems unlikely that length is the causal factor. It seems probable that one or a combination of the other three may be at fault.

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GROSS STATIC LIFTING CAPACITY OF LOGGING BALLOONS

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ABSTRACT

Logging balloons, in a range of sizes, are operated in a variety of atmospheric conditions. The influence of these conditions upon the gross static lifting capacity of the balloon can be computed from the fundamental principles of aerostatics and thermodynamics. This research paper discusses the parameters influencing static lift and shows how it can be computed. Nomographs are provided for field computation of gross static lift from values of pressure, temperature, and volume. This information may be used by the balloon logger as he studies his balloon performance and monitors gas loss during operation.

Keywords: Balloon logging, aerial logging, logging, logging equipment.

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NOMENCLATURE

Symbol		*Abbreviation of unit of measure*
L	Gross static lift	lb.
p	Pressure	lb./ft.^{2}
p_D	Design pressure, lowest pressure expected during balloon operation	lb./ft.^{2}
p_v	Partial pressure of the water vapor	lb./ft.^{2}
p_w	Vapor pressure corresponding to the wet-bulb temperature	lb./ft.^{2}
R	Perfect gas constant	(ft.-lb./lb.-°R)
T	Temperature	°R or °F.
T_d	Dry-bulb temperature	°F.
T_D	Design temperature, highest gas temperature expected during balloon operation	°R or °F.
T_w	Wet-bulb temperature	°F.
V_D	Design volume of the balloon, volume occupied by lifting gas when the balloon is fully inflated	ft.^{3}
V_g	Volume of lifting gas contained in the balloon	ft.^{3}
V_{STD}	Volume occupied by lifting gas at standard conditions of temperature and pressure	ft.^{3}
w	Density	lb./ft.^{3}
W_g	Weight of lifting gas	lb.
a	Air	
g	Lifting gas	
m	Mixture of dry air and water vapor	

1.0 INTRODUCTION

Fundamental to design and operation of the logging balloon is determination of its gross static lift capability and how lift is influenced by size, lifting gas properties, and atmospheric environment. These are static considerations which ignore the effects of the dynamics and aerodynamics of operation. Although dynamics and aerodynamics must be considered in a complete design of the logging balloon, only static lift considerations are discussed in this paper.

Ability to compute static lift is required of the balloon logger for several reasons. Possibly the most obvious requirement for this knowledge is for predicting the change in lifting potential of a given balloon as it moves from one operation to another. As environmental conditions are then changed, the influence upon the balloon static lift potential could become an important design consideration. Accurate knowledge of static lift also becomes necessary in a program for monitoring gas loss. A nearly constant rate of gas loss is expected in most balloons due to natural diffusion through the fabric. Additional loss through holes or other damage points in the balloon will increase this loss. Monitoring the gas loss by periodic measurement of net lift and performing the calculations discussed in this paper can aid in early detection of additional loss through holes. An example is included to describe this procedure.

2.0 LIFTING GASES

Several gases are available for balloon inflation, each with its advantages and disadvantages. The single requirement is that the gas be much lighter than air or can be made so with a moderate amount of heating. The commonly used lifting gases and their properties are listed in table 1.

Hydrogen, the lightest of all gases, is highly flammable over a wide range of concentrations in air. Accidents with hydrogen have made designers and users leery of its application.

Helium, the next lightest gas, has the attractive feature of being completely inert. Despite its high cost, helium has generally been considered the most suitable gas for a logging balloon.

Ammonia lacks the lifting potential of helium or hydrogen but is attractive from the standpoint of availability and cost. Ammonia is an inexpensive gas which can be generated from anhydrous ammonia on site for inflation of a logging balloon. However, it is incompatible with conventional balloon fabrics[1] and glues and has relatively high density.

Table 1.—*Gas properties at 68° F. and standard atmospheric pressure*

Property	Hydrogen	Helium	Ammonia	Air
Molecular weight	2.0	4.0	17.0	29.0
Density, $\frac{\text{lb.}}{\text{ft.}^3}$	0.00523	0.0104	0.0442	0.0753
Density relative to air	0.0695	0.138	0.587	1.0
Gas constant, $\frac{\text{ft.-lb.}}{\text{lb.-}^\circ\text{R}}$	766.8	386.3	90.77	53.3
Specific heat, $\frac{\text{B.t.u.}}{\text{lb.-}^\circ\text{R}}$	3.42	1.25	0.523	0.241
Gross lift per 1,000 cubic feet, lb.	70.7	64.9	31.1	–

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[1] Hilton H. Lysons. Compatibility of balloon fabrics with ammonia. Pac. Northwest Forest & Range Exp. Sta USDA Forest Serv. Res. Note PNW-42, 9 p., illus., 1966.

Hot air has advantages of availability, cost, stability, and compatibility with fabrics but the one serious disadvantage of requiring a heat source. Experience with hot air balloons indicates the energy requirement for a logging balloon would range in the millions of B.t.u.'s per hour. The operation and fuel requirements of such a configuration can be readily seen to present major problems in the woods.

3.0 GROSS STATIC LIFT

That portion of a logging balloon's total lift attributable to its buoyancy is referred to as static lift. The upward force, or buoyant force, equals the weight of the volume of air displaced by the balloon. Reducing the buoyant force by the weight of gas in the balloon yields the gross static lift. The gross static lift of the balloon is given by

$$L = (w_a - w_g)V_g.$$

The net upward force acting on the balloon tether line equals the gross static lift of the balloon less the constant tare of bag, support lines, tether line, safety line, etc. Gross static lift, on the other hand, may vary considerably with changes in atmospheric conditions. The following discussion is restricted to the factors affecting the gross static lift of the balloon. The balloon's environment is considered at rest, and pressures, temperatures, and densities discussed are taken as static values.

3.1 Balloon Type

The balloon type found most useful for logging applications is the flabby balloon, constructed with a ballonet section. A cross section of a typical balloon is shown in figure 1. One desirable feature of this design is that gross static lift is almost independent of ambient conditions since gas volume expands or contracts in response to atmospheric pressure and temperature changes.

The normal operating mode of the flabby balloon is the partially inflated condition. In this condition, lift of the balloon will not vary with atmospheric changes in temperature and pressure, providing gas temperature inside the balloon is the same as outside air temperature. The technical discussion supporting this is presented in Appendix A.

Figure 1.—Flabby balloon with ballonet: ***A*****, Partially inflated;** ***B*****, fully inflated.**

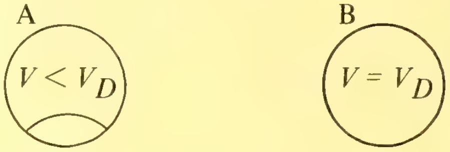

Figure 1B shows the balloon in fully inflated condition. For purposes of discussion, volume in the bag when fully inflated will be called the design volume of the balloon. Once gas has expanded to design volume, additional expansion will either pressurize the gas or force gas out of the balloon. Many flabby balloons are equipped with pressure relief valves to prevent rupture. It is good operating practice to initially underinflate the balloon to accommodate gas expansion expected during the balloon's operation.

It will be assumed in the discussion to follow that initially the balloon was underinflated enough to prevent gas expansion beyond the design volume of the balloon. Therefore, volume of gas is always less than or just equal to design volume.

3.2 Atmospheric Pressure and Temperature Effects

A derivation of equations expressing influence of pressure and temperature is presented in Appendix A. It is shown that dependence of static lift upon pressure can be expressed as a function of the ratio of balloon gas pressure to balloon ambient air pressure. For a flabby balloon, pressure of the gas in essentially the same as atmospheric pressure, and the pressure ratio is always equal to unity. Therefore, for a balloon containing a given amount of gas, gross static lift does not depend upon atmospheric pressure. Gas pressure adjusts to external air pressure, and gas volume changes accordingly. As long as the gas volume does not exceed the design volume of the balloon, changes in volume occur naturally with changes in pressure such that there is no change in gross static lift.

Dependence of gross static lift on temperature is similar to the pressure dependence; i.e., lift depends on the ratio of temperature of gas to temperature of air. It is useful when discussing the effects of temperature on lift to use the term "superheat." Superheat is equal to gas temperature minus air temperature. When gas temperature and air temperature are equal (zero superheat), lift is independent of temperature. The condition of no superheat is the exception rather than the rule. The normal operating condition is one of positive superheat; i.e., the temperature of gas is greater than temperature of air. The temperature of gas in the balloon will rise until the heat input from solar radiation is balanced by heat loss due to convection. Convection heat loss is directly proportional to superheat. Heat input from solar radiation is greatest for clear, sunny days. Therefore, on clear, sunny days the balloon lift is greater due to the greater amount of superheat required to balance the solar radiation heat input to the balloon. Since the superheat condition is more pronounced on sunny days, the variation in lift has sometimes been incorrectly attributed to atmospheric temperature changes.

Accurate prediction of the amount of superheat that a balloon will experience during its operating life is important to the balloon operator. Overestimating the potential amount of superheat will cause a loss in load-carrying capacity because the balloon is not initially inflated to capacity. Underestimating the amount of superheat may require dumping helium overboard to prevent overpressurizing the balloon at extreme operating conditions. Although methods are available to compute approximations[2] of superheat which depend upon balloon volume, material, shape, and atmospheric conditions, they are beyond the scope of this paper. Direct measurement of balloon gas temperature would be the most practical means of assessing the superheat.

3.3 Humidity

Humidity variations in the atmosphere affect lift in two ways. First, gross static lift is slightly less on a humid day because density of humid air is less than density of dry air. The percent change in gross static lift due to this effect is discussed in Appendix B.

A second effect of humidity is to add a variable tare weight to the balloon by condensation. A coat of dew may add over 1,000 pounds of weight on a 500,000-cubic-foot balloon. The condensation is most troublesome when comparing successive static lift measurements to monitor gas loss. Since corrections to lift measurements for effect of condensation would be subject to large errors, the best approach is to avoid taking lift measurements when condensation can be seen on the bag.

3.4 Purity

Gross static lift is directly proportional to purity of lifting gas. Lifting gas is generally delivered nearly 100 percent pure; however, air can be expected to diffuse into the balloon during inflation and operation. For example, a balloon containing 95 percent by volume pure helium generates 95 percent of the lift of the same balloon containing 100 percent of pure helium.

4.0 CALCULATIONS OF BALLOON STATIC PERFORMANCE

A series of examples are presented to demonstrate procedures for determining balloon requirements and characteristics. These calculations all depend upon equations presented in Appendix A. Although the equations of Appendix A require relatively simple calculations, need for a calculator or slide rule can require a cumbersome computing routine for in-field application. To simplify the operation, nomographs have been included in this paper. A nomograph is a convenient device frequently used to represent an equation and to avoid arithmetic computations. The nomographs of this paper provide means to compute air density, gas density (fig. 2), and gross static lift per pound of gas (fig. 3) for the range of pressures and temperatures occurring in balloon logging. These nomographs have been prepared for helium since it is presently the usual lifting gas for logging balloons.

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[2] E. R. G. Eckert and Robert M. Drake, Jr. Heat and mass transfer. New York, McGraw-Hill, 530 p., illus., 1959.

4.1 Initial Inflation Requirements

Problem statement: What is the initial inflation requirement and expected gross static lift for a helium-filled balloon operating in a given environment? The expected operating conditions are a maximum pressure altitude[3] of 5,000 feet and a high in air temperature of 80° F. In addition, 40° F. of superheat is expected at maximum temperature.

Problem solution: The density nomograph can be used to determine the inflation requirements of the balloon. With inputs of pressure altitude and gas temperature, including superheat, gas density in pounds per cubic foot can be determined. The product of density and initial inflation volume of the balloon will establish the amount of helium required. Assuming the balloon is to be filled to a design volume of 250,000 cubic feet, the solution would proceed as follows.

Figure 4 determines a balloon gas density of 0.00786 pounds per cubic foot from the expected operating conditions of 5,000 feet pressure altitude and 120° F. gas temperature. At this density, the weight of helium in a 250,000-cubic–foot balloon would be

$$(250{,}000)\ (0.00786) = 1{,}965 \text{ pounds.}$$

If the helium requirements are desired in standard cubic feet, as normally delivered by the compressed-gas industry, the value must be referenced to their standard conditions[4] of pressure and temperature. If standard conditions of temperature 32° F. and pressure 29.92 inches of mercury are assumed, the standard density of helium is 0.01113 pounds per cubic foot. The cubic feet required at these standard conditions in the example above becomes

$$V_{STD} = \frac{w}{w_{STD}}\ V = \frac{0.00786}{0.01113}(250{,}000) = 176{,}550 \text{ cubic feet.}$$

The second part of the problem—determination of expected gross static lift—uses the lift nomograph for solution (fig. 5). This nomograph determines gross static lift per pound of gas which depends upon gas and air temperatures only. For this example, the result is 6.78 pounds of lift per pound of helium. Since the balloon is expected to contain 1,965 pounds of helium, the gross static lift would be

$$L = (6.78)\ (1{,}965) = 13{,}317 \text{ pounds of lift.}$$

If the balloon is not in the superheat condition, a lift of 6.25 pounds per pound of helium is determined from the nomograph. This gives a lift of

$$L = (6.25)\ (1{,}965) = 12{,}281 \text{ pounds of lift.}$$

4.2 Balloon Relocation

Problem statement: A 250,000-cubic-foot (design volume) balloon containing 1,965 pounds of helium is to be moved in its inflated condition to a new logging site. The extreme operating conditions of the new site are:

Pressure altitude	8,000 feet
Expected maximum gas temperature	100° F.
Expected maximum air temperature	80°F.

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[3] Pressure altitude is the reading of an altimeter when adjusted to the standard sea-level atmospheric pressure of 29.98 inches of mercury. Since it reflects the ambient temperature and atmospheric pressure, pressure altitude may not correspond to the actual elevation.

[4] Goodyear Aerospace Corporation. Tethered balloon handbook. Final report, May 1968-December 1968, 221 p., illus.

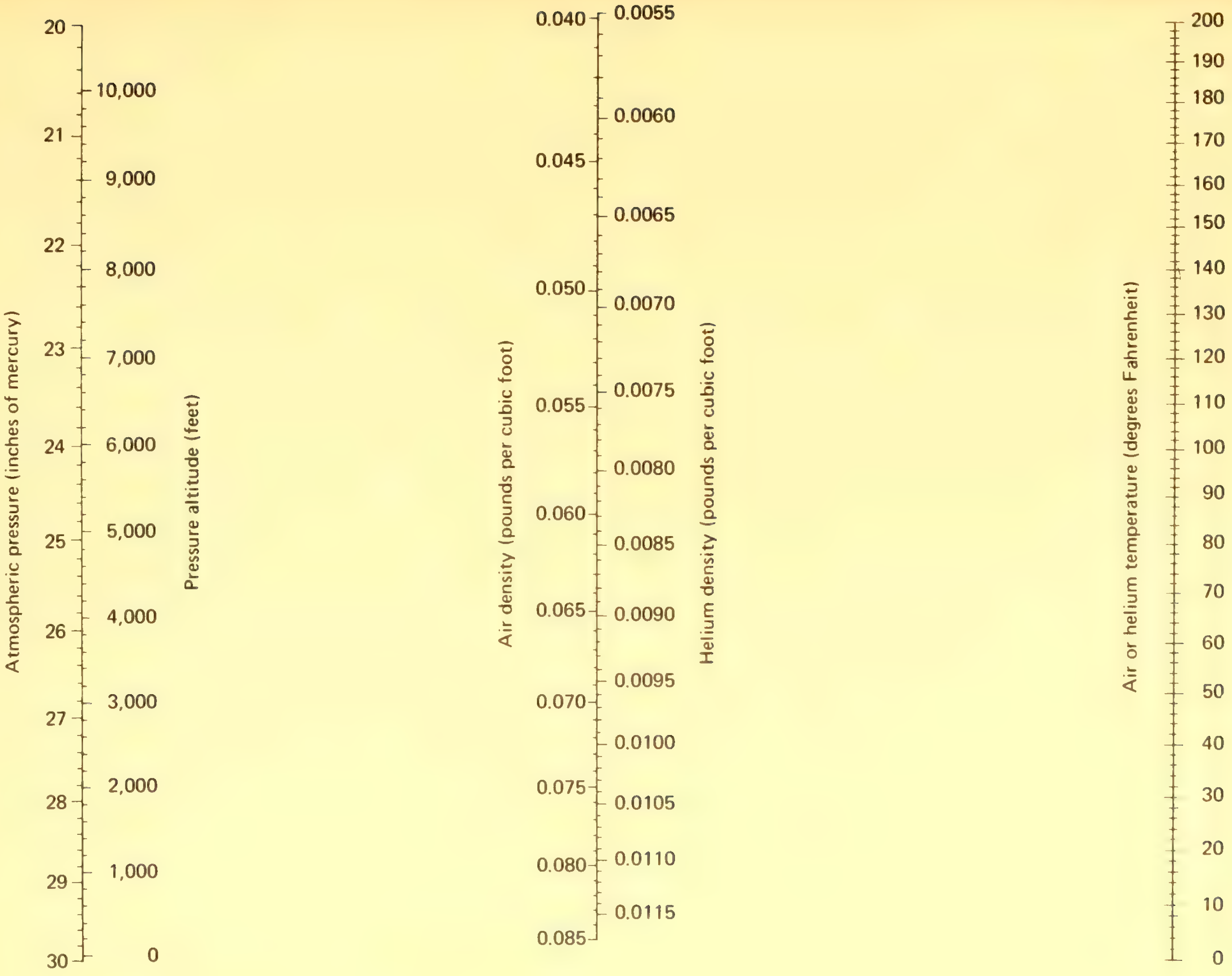

Figure 2.—Density nomograph.

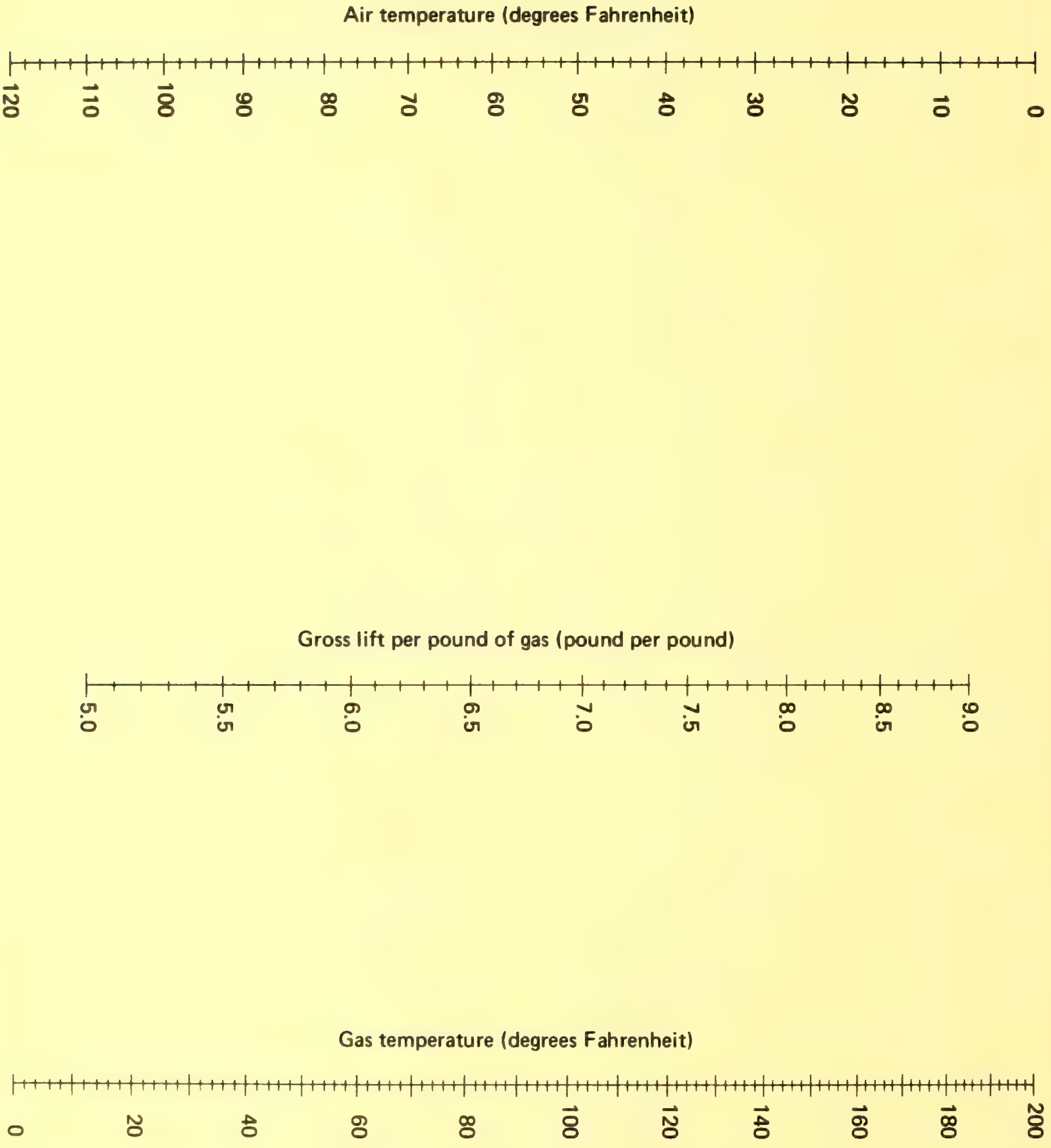

Figure 3.—Lift nomograph.

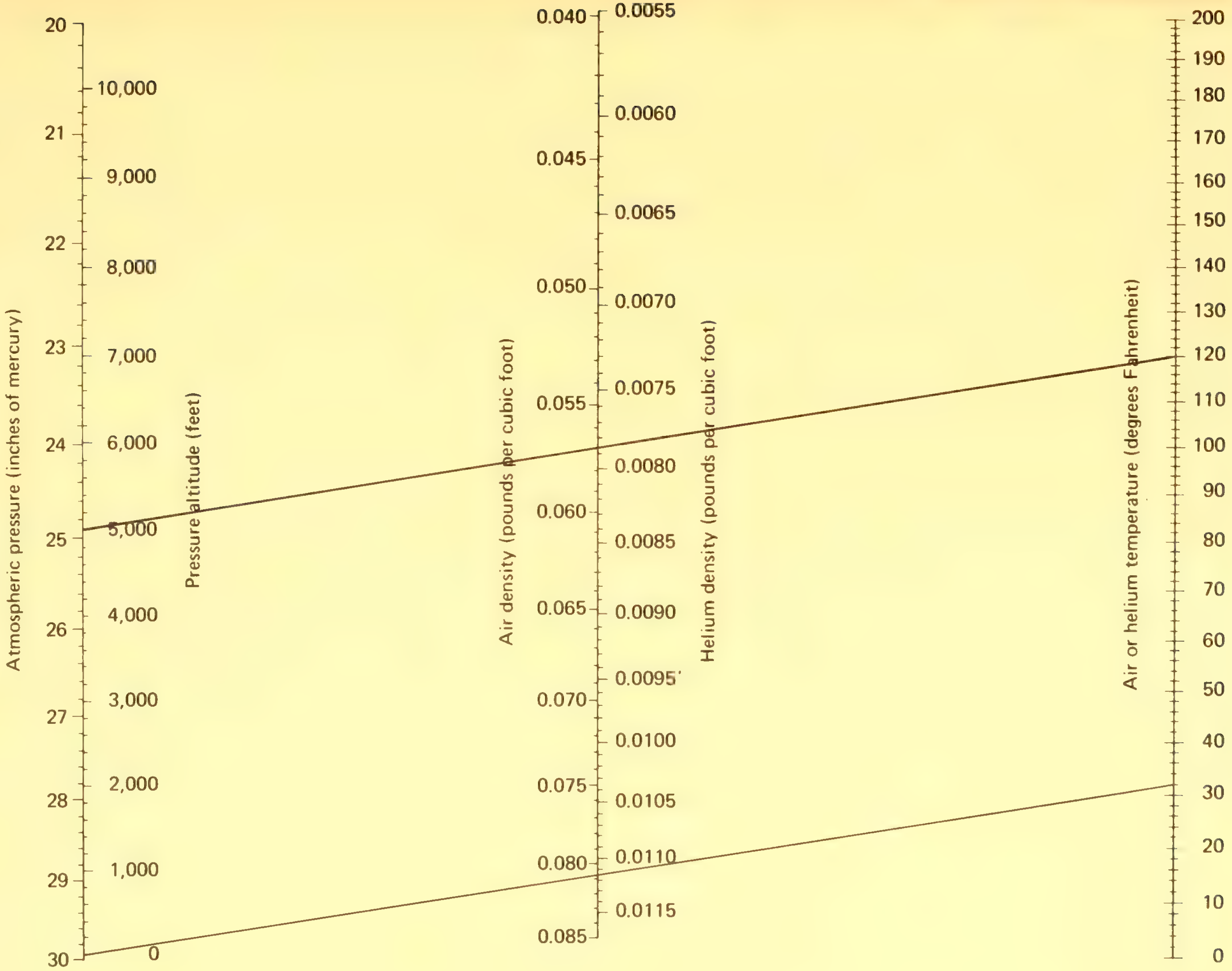

Figure 4.—Nomograph for determining initial inflation requirements.

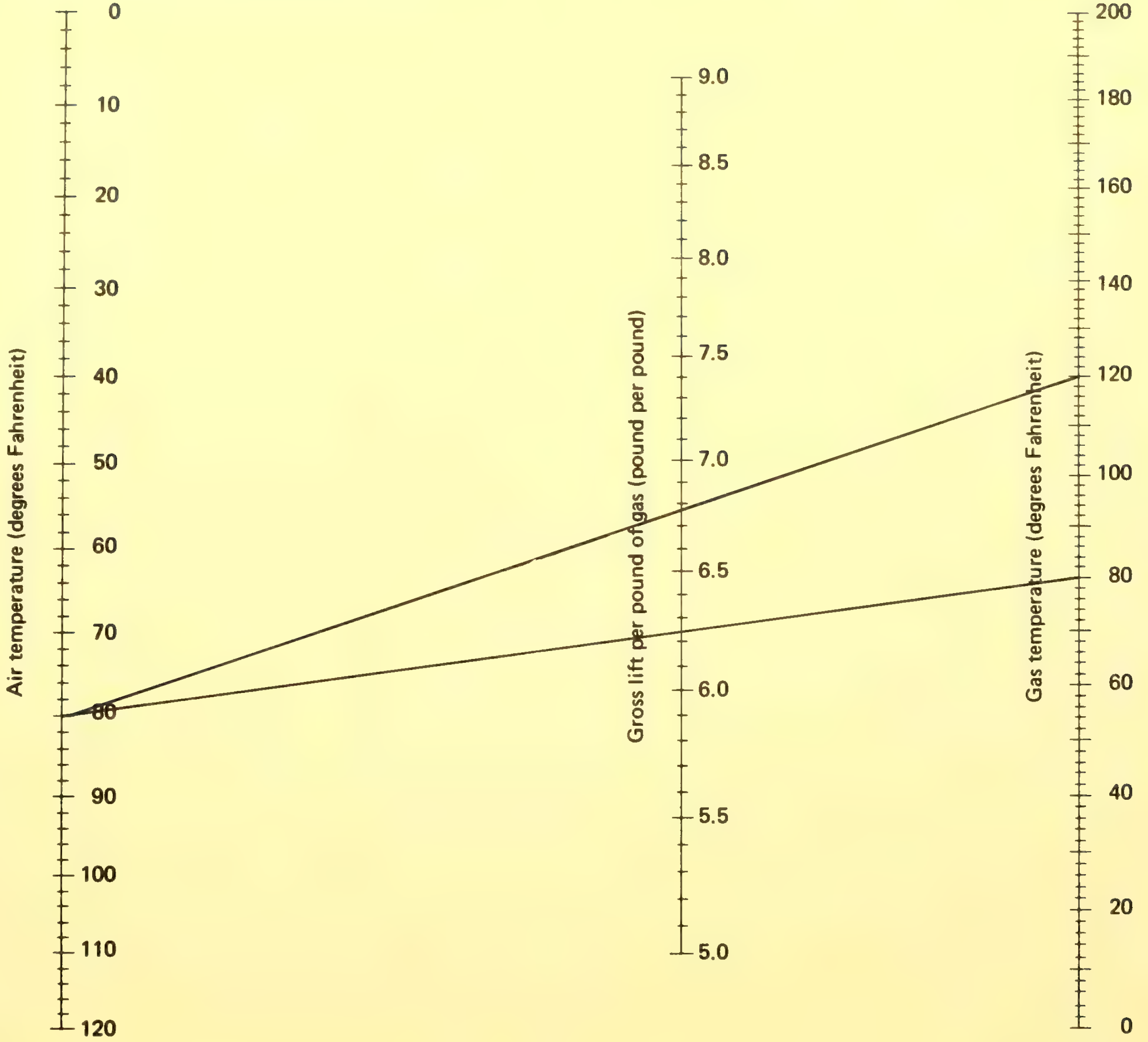

Figure 5.—Nomograph for determining initial inflation requirements.

Will the balloon be overpressurized if relocated to these operating conditions? If so, how much helium should be removed, and what is the associated loss in lift at the zero superheat condition?

Problem solution: If 1,965 pounds of helium occupies the 250,000 cubic feet of balloon capacity, the gas would have a density of 0.00786 pound per cubic foot. If this gas was at the anticipated extreme gas temperature of 100° F., the nomograph of figure 6 indicates gas would be at a pressure of 24.04 inches of mercury. This is higher than 22.23 inches of mercury, which is the atmospheric pressure corresponding to 8,000 feet pressure altitude. This means that gas pressure inside the balloon would exceed atmospheric pressure and could lead to structural failure of the balloon. If a pressure relief valve was provided, it would open, releasing sufficient helium to maintain pressure inside the balloon within allowable limits.[5]

When helium is dumped intentionally before moving or through a relief valve while moving, the weight of gas which remains in the balloon can be computed. The conditions of 8,000 feet pressure altitude and 100° F. gas temperature are used to determine expected gas density at the new site. Figure 6 shows this to be 0.00727 pound per cubic foot. If the balloon is filled to the 250,000-cubic-foot volume at this density, weight of gas contained would be

$$W_g = (0.00727)\,(250{,}000) = 1{,}817 \text{ pounds of helium.}$$

This indicates that 148.0 pounds of gas would have to be removed or would be lost in moving to the new site.

4.3 Monitoring Gas Loss

Consecutive sets of lift measurements are taken for the purpose of monitoring gas loss. In addition to net lift, the following data are required to calculate weight of helium contained in the balloon: gas temperature, atmospheric temperature, tare, and holddown geometry. Gas weight calculations are illustrated by the following example:

Measured and known quantities:

Net lift measured in tether line	10,000 pounds
Air temperature around balloon	60° F.
Helium temperature in balloon	60° F.
Known tare for this balloon	3,500 pounds

Figure 7 shows how gas and air temperatures determine gross lift per weight of gas. This lift, 6.25 pounds per pound of gas, and the gross static lift of 13,500 pounds (net lift plus tare weight) indicate the balloon contains

$$W_g = \frac{13{,}500 \text{ pounds}}{6.25 \text{ pounds per pound}} = 2{,}160 \text{ pounds of helium.}$$

Similar data, taken at periodic intervals, could be used to monitor the amount of helium contained in the balloon. Such a collection of data is plotted in figure 8. The observer will notice some scatter in these data due to errors in measurement and uncertainties in helium purity, humidity, relative wind, condensation on the balloon, and holddown geometry. However, reliable trends can be developed as these errors should average, and trends are most important to the balloon operator. A gradual decrease in the curve may indicate a slow leak, or a sharp drop may indicate that a more serious condition exists. A record of makeup gas required can also be facilitated with figure 8.

---

[5] Pressure in the balloon will be greater than atmospheric pressure since relief valves are activated by a slight overpressure. In calculations of gas loss through valves, however, assumption of equal pressures inside and outside the bag is made. This assumption yields a slightly conservative estimate for gas loss.

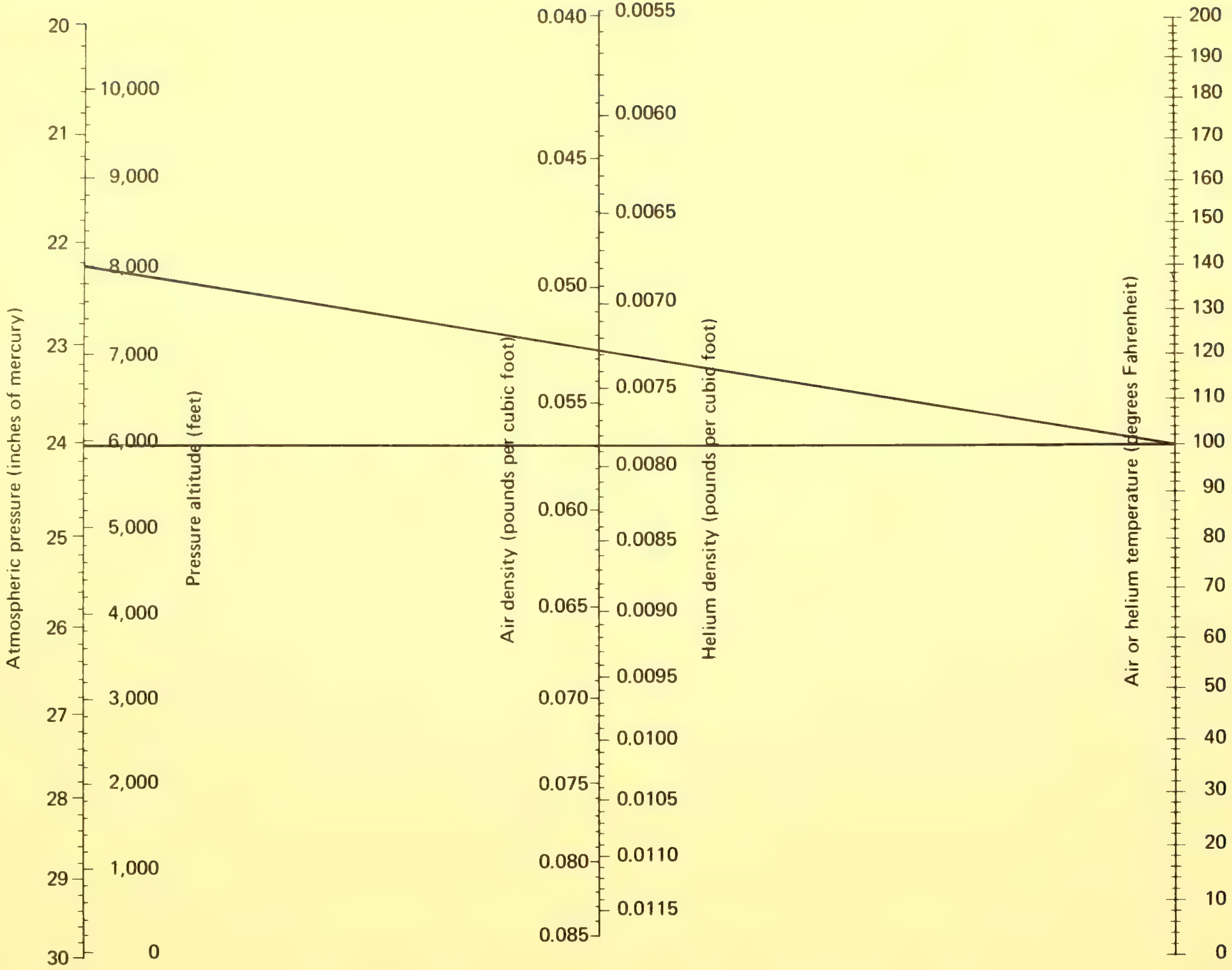

Figure 6.—Nomograph for balloon relocation analysis.

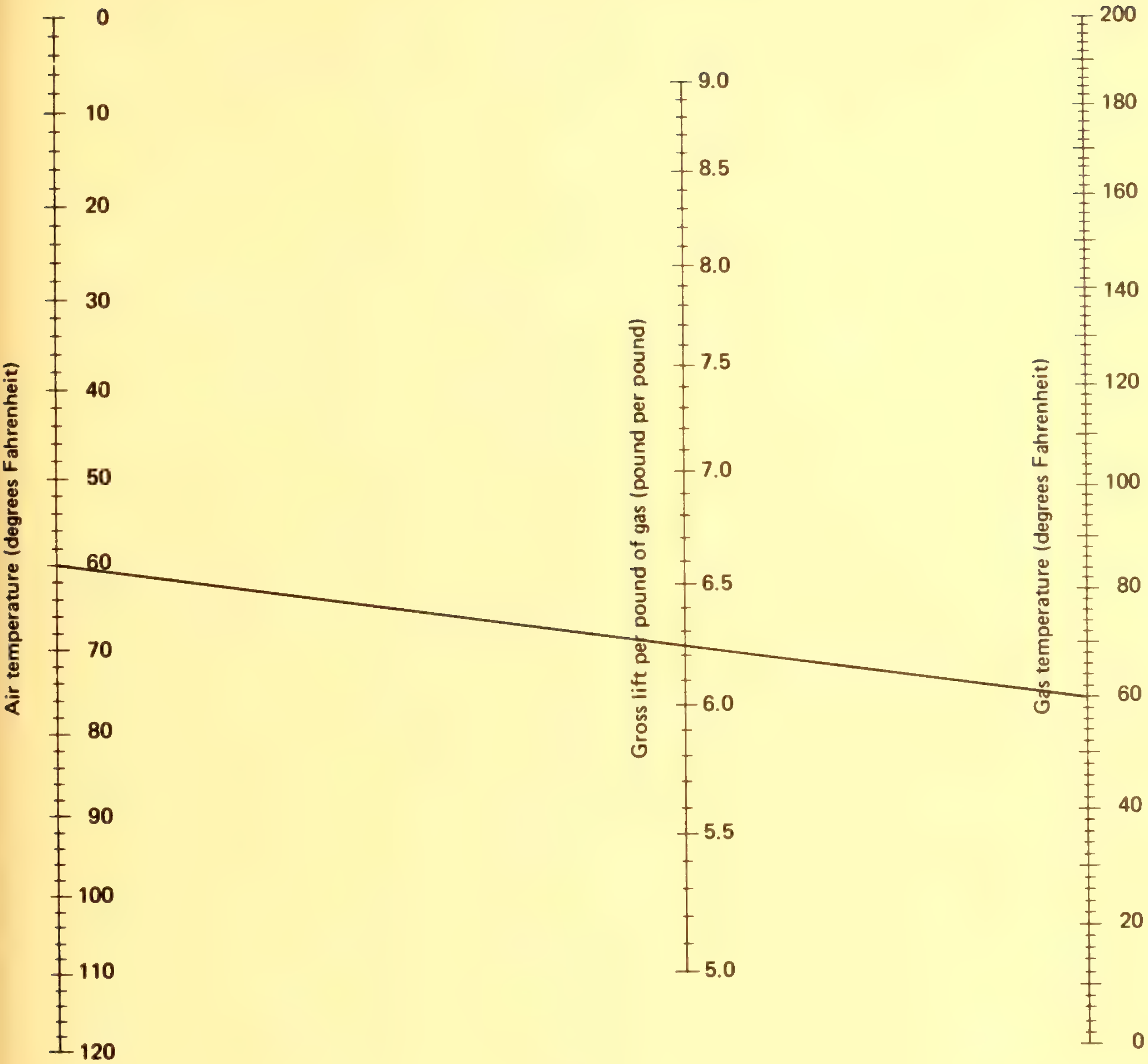

Figure 7.—Nomograph for monitoring gas loss.

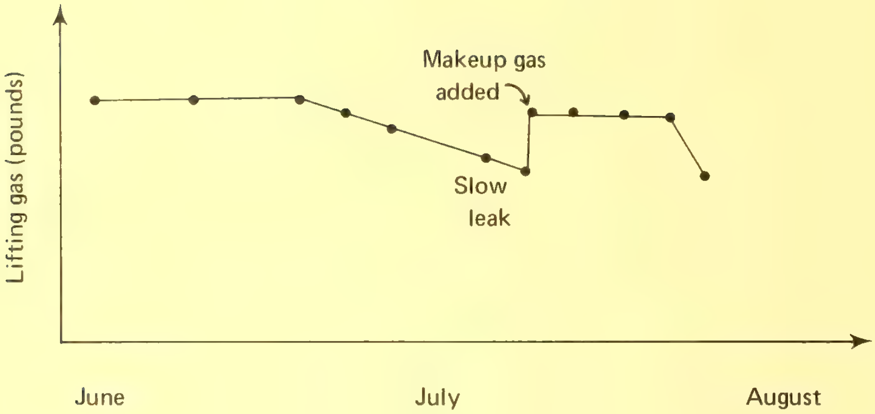

Figure 8.—Record of lifting gas stored in balloon.

APPENDIX A

GROSS STATIC LIFT AS AFFECTED BY PRESSURE, TEMPERATURE, AND LIFTING GAS VOLUME

Lift of a lighter-than-air balloon can be calculated from the principle of buoyancy. Gross upward lift experienced by the balloon is equal to weight of displaced air less weight of an equal volume of lifting gas. In algebraic terms, we have

$$L = (w_a - w_g)V_g. \tag{1}$$

To predict effects of pressure and temperature changes on lift, pressure and temperature have to be related to weight of air and lifting gas by the equation of state. Both air and lifting gas can be considered as ideal gases. Their respective equations of state are

$$p_A = w_a R_a T_a$$

and

$$p_g = \frac{W_g R_g T_g}{V_g} = w_g R_g T_g. \tag{2}$$

Mass of gas used to initially inflate the balloon is determined by requiring, during inflation, that the lifting gas expand to fill the balloon at the extreme pressures and temperatures to be encountered during the logging operation. We can use equation 2 to state this requirement analytically.

$$V_g = \frac{W_g R_g T_g}{p_g} \leq V_D \text{ for all } T_g \text{ and } p_g. \tag{3}$$

Equation 3 states that at all operating conditions of pressure and temperature, volume occupied by the lifting gas has to be less than or equal to design volume of the balloon.

Therefore, the amount of lifting gas used to initially inflate the balloon (takeoff inflation) is given by

$$W_g = \frac{p_D V_D}{R_g T_D}. \tag{4}$$

Where,

V_D = gas volume with fully extended ballonet, a design parameter of the balloon,

R_g = perfect gas constant of the lifting gas, property of the lifting gas,

p_D = lowest pressure experienced by the lifting gas during operation. Since the pressure inside the balloon in a still air environment is the same as the pressure outside the balloon, this is numerically the same as the lowest atmospheric pressure during operation,

T_D = highest absolute temperature experienced by the lifting gas during operation. This will be higher than the highest atmospheric temperature expected since the normal operating condition will be one of positive superheat.

Using this information and the equations of state, we can obtain an expression for the gross lift of a balloon in terms of pressure and temperature

$$L = W_g \left(\frac{p_a R_g T_g}{p_g R_a T_a} - 1\right). \tag{5}$$

Applying the boundary condition that the pressure is the same inside and outside the balloon (that is, $p_a = p_g$), we have the following important result,

$$L = W_g \left(\frac{R_g T_g}{R_a T_a} - 1\right). \tag{6}$$

The atmospheric pressure exerted on the balloon will change with local weather conditions or changes in altitude; however, the lift, L, experienced by the balloon will not change with air pressure changes. This is algebraically expressed by equation 6.

The effect of initial inflation is clearly demonstrated in equation 6. Since lift is directly proportional to the weight of lifting gas, the object is to put in as much gas as possible without overinflating the balloon. The correct amount of initial gas is given by equation 4. Overinflation will result in loss of inflation gas at extreme operating conditions of pressure and temperature, with a consequent loss in lift capability and financial loss.

The effect of temperature is shown in equation 6. The gross lift is constant as long as the gas temperature inside the balloon is the same as the air temperature outside. This is not the usual situation, however. Normally, $T_g > T_a$, and the lift is increased as the gas temperature increases over the air temperature. The superheat is greater on warm days with clear skies, accounting for the observations of increased lift under such conditions.

APPENDIX B

EFFECTS OF HUMIDITY

Moist air is a mixture of water vapor and dry air; and since both are perfect gases, moist air is a perfect gas. The following equations of state apply to these perfect gases:

$p_m = w_m R_m T_m$ for an atmosphere of dry air and water vapor mixture;

also,

$p_a = w_a R_a T_a$ for dry air

and

$p_v = w_v R_v T_v$ for water vapor. (1)

The perfect gas constant for the air-vapor mixture can be related to the gas constants for air and vapor, respectively. Dalton's law states the total pressure of a mixture of gases is equal to the sum of the partial pressures of the constituents when each constituent occupies the volume of the mixture at the same temperature as that of the mixture. A mathematical statement of Dalton's law is

$$p_m = p_a + p_v$$

$$w_m = w_a + w_v$$

$$T_m = T_a = T_v . \qquad (2)$$

Combining equations 1 and 2, and using $\frac{R_a}{R_v} = 0.622$, we arrive at the following,

$$R_m = R_a \frac{p_m}{p_m - 0.378\, p_v} \quad \frac{\text{ft.-lb.}}{\text{lb.-}^\circ\text{R}} \qquad (3)$$

Equation 3 allows calculation of the perfect gas constant for any air-water vapor mixture, provided the total pressure of the mixture (barometric pressure) and the partial pressure of the water vapor are known. The vapor pressure is not directly measurable; however, it can be determined with a semiempirical expression giving the vapor pressure as a function of measurable quantities, namely

$$p_v = p_w - \frac{(p_m - p_w)(T_d - T_w)}{2{,}800 - 1.3\, T_w} . \qquad (4)$$

The dry-bulb and wet-bulb temperatures can be measured with a sling psychrometer. The vapor pressure corresponding to the wet-bulb temperature can be read from steam tables. The temperatures should be expressed in degrees Fahrenheit for use in the formula.

The gross static lift of a balloon in humid air is

$$L\,(\text{moist air}) = W_g\,(\frac{R_g T_g}{R_m T_a} - 1). \tag{5}$$

The gross static lift in dry air is

$$L\,(\text{dry air}) = W_g\,(\frac{R_g T_g}{R_a T_a} - 1). \tag{6}$$

We can see from equation 3 that R_m is always greater than or equal to R_a. Therefore, the balloon lift in humid air is always less than or equal to the lift in dry air. Table 2 shows the effect of humidity on lift. This effect is second-order and not worth making corrections for in-field calculations.

Table 2.—*Comparison of static lift in dry and saturated air*[1]

Atmospheric temperature	Vapor pressure	Lift in dry air	Lift in saturated air	Loss in lift
	Pounds per square inch	*Pounds*	*Pounds*	*Percent*
0° F.	0.018	12,500	12,493	0.06
10° F.	.031	12,500	12,488	.10
20° F.	.052	12,500	12,480	.16
30° F.	.084	12,500	12,470	.24
40° F.	.121	12,500	12,450	.40
50° F.	.178	12,500	12,430	.56
60° F.	.256	12,500	12,400	.80
70° F.	.363	12,500	12,360	1.12
80° F.	.507	12,500	12,310	1.52
90° F.	.698	12,500	12,240	2.08

[1] Conditions are: atmospheric pressure = 14.7 pounds per square inch; lifting gas—pure helium, 2,000 pounds or 179,500 cubic feet (32° F.), 14.7 pounds per square inch; and no superheat.

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RUNNING SKYLINE DESIGN WITH A DESK-TOP COMPUTER/PLOTTER

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ABSTRACT

The procedure for determination of running skyline load-carrying capability is discussed. A desk-top computer/plotter is employed to plot terrain profiles and determine and plot the path of a loaded running skyline carriage. The computer programs implementing the procedure are included. The paper is intended for the designer who is investigating the use of running skylines in harvesting plans.

Keywords: Skyline logging, logging operations, computer programs, logging.

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1.0 INTRODUCTION

The running skyline system is being used by an increasing number of timber operators for thinning and clearcutting. It is a system of two or more suspended moving lines, generally referred to as main and haulback, that when properly tensioned will provide lift and travel to the suspended load.[1] A grapple-rigged system is illustrated in figure 1.

The logging system designer who is considering the application of a running skyline system must determine its load-carrying capability over a given ground profile. There are basically three means for assessing this capability: a graphical-tabular handbook approach as presented by Lysons and Mann,[2] [3] a mathematical solution utilizing the large digital computing facilities,[4] or a mathematical solution utilizing small desk-top computers. All these methods are directed to the problem of determining the load-carrying capability of running skylines; however, there is a difference in approach. The procedures presented in references 2, 3, and 4 determine the load that can be carried under given conditions of deflection, whereas the desk-top computer approach presented here determines deflection, and ultimately a load path, for a specified load. This note discusses the approach and the implementation of solution on the desk-top computer. The mathematical features of the problem are discussed in a paper by Carson and Mann.[5]

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[1] Anonymous. Glossary of cable logging terms. Pac. Northwest Forest & Range Exp. Sta. USDA Forest Serv., 7 p., 1969.

[2] Hilton H. Lysons and Charles N. Mann. Skyline tension and deflection handbook. Pac. Northwest Forest & Range Exp. Sta. USDA Forest Serv. Res. Pap. PNW-39, 41 p., illus., 1967.

[3] Charles N. Mann. Mechanics of running skylines. Pac. Northwest Forest & Range Exp. Sta. USDA Forest Serv. Res. Pap. PNW-75, 11 p., illus., 1969.

[4] Stanley K. Suddarth. Analysis of cable systems--the grapple-rigged running skyline. Skyline Logging Symp. Proc., Oreg. State Univ., 1970.

[5] Ward W. Carson and Charles N. Mann. Analysis of running skyline load path. Pac. Northwest Forest & Range Exp. Sta. USDA Forest Serv. Res. Pap. In preparation.

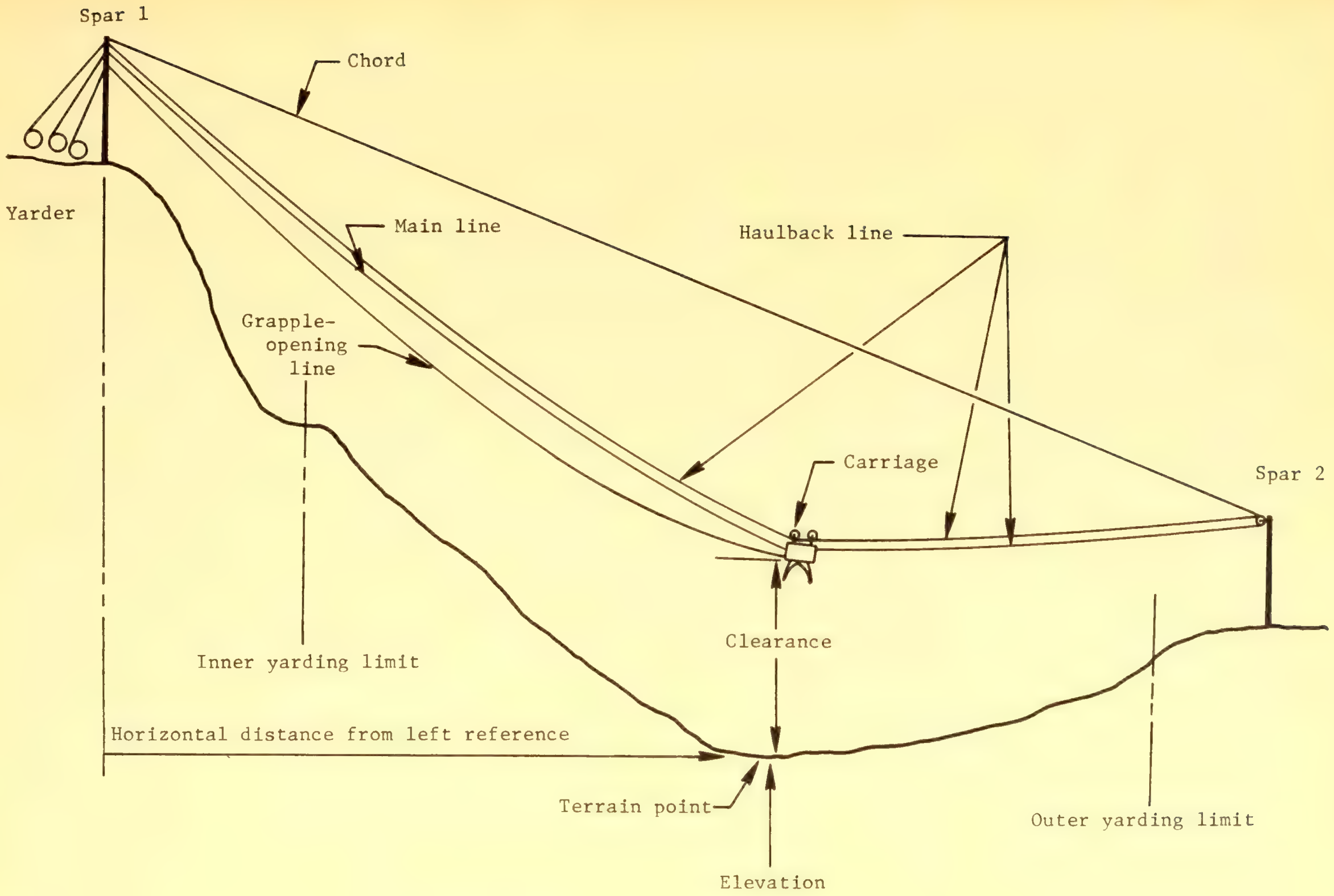

Figure 1.—Running skyline nomenclature.

2.0 DESK-TOP COMPUTER SYSTEM

The recent development of desk-top computers and plotters now makes it possible to obtain on-the-job solutions of many problems that previously were referred to large central computing facilities. These desk-size machines have memories that enable them to store instructions and constants for repetitive or iterative solutions. The programs for these computers are written in keyboard language and can be stored magnetically when desired. The capability of the computer is determined by the number of storage registers that it provides.

A plotter and a printer may be used in conjunction with the computer. The plotter provides a graphic display of the solutions to the problems solved. It plots the points specified by the calculator when instructed to do so.

The printer will print the contents of the calculator's display registers upon manual or programed command. It can also list the contents of the calculator's program memory.

A typical desk-top computer system is shown in figures 2, 3, and 4.

3.0 PHYSICAL PROBLEM

To determine the feasibility of individual skyline roads in a logging plan, the designer must compute the capability of the running skyline system. Capability is a function of both allowable line tension and deflection which is limited by terrain. Line tensions are controlled by the yarder, and the deflection of the system results from the load which is being supported. The profile of the skyline road is established by the designer from ground profile data, obtained from contour maps, stereophotograph models, or from ground measurements. The designer specifies the cable sizes and an operating tension in the haulback line. The question at this point of design is "Will the anticipated load clear the ground profile?" The answer can be provided by a desk-top computer.

The anticipated load on a running skyline varies with the conditions of the operation. If there is a requirement to "fly" logs clear of the ground, the total weight must be supported by the lines, and clearance must be provided above the ground. If the logs can be yarded with one end resting on the ground, which is generally the case when logging uphill or on level ground, the lines support only the weight of the carriage and a fraction of the weight of the logs. Allowing some ground support of the logs also reduces clearance requirements which, in turn, increases capability.

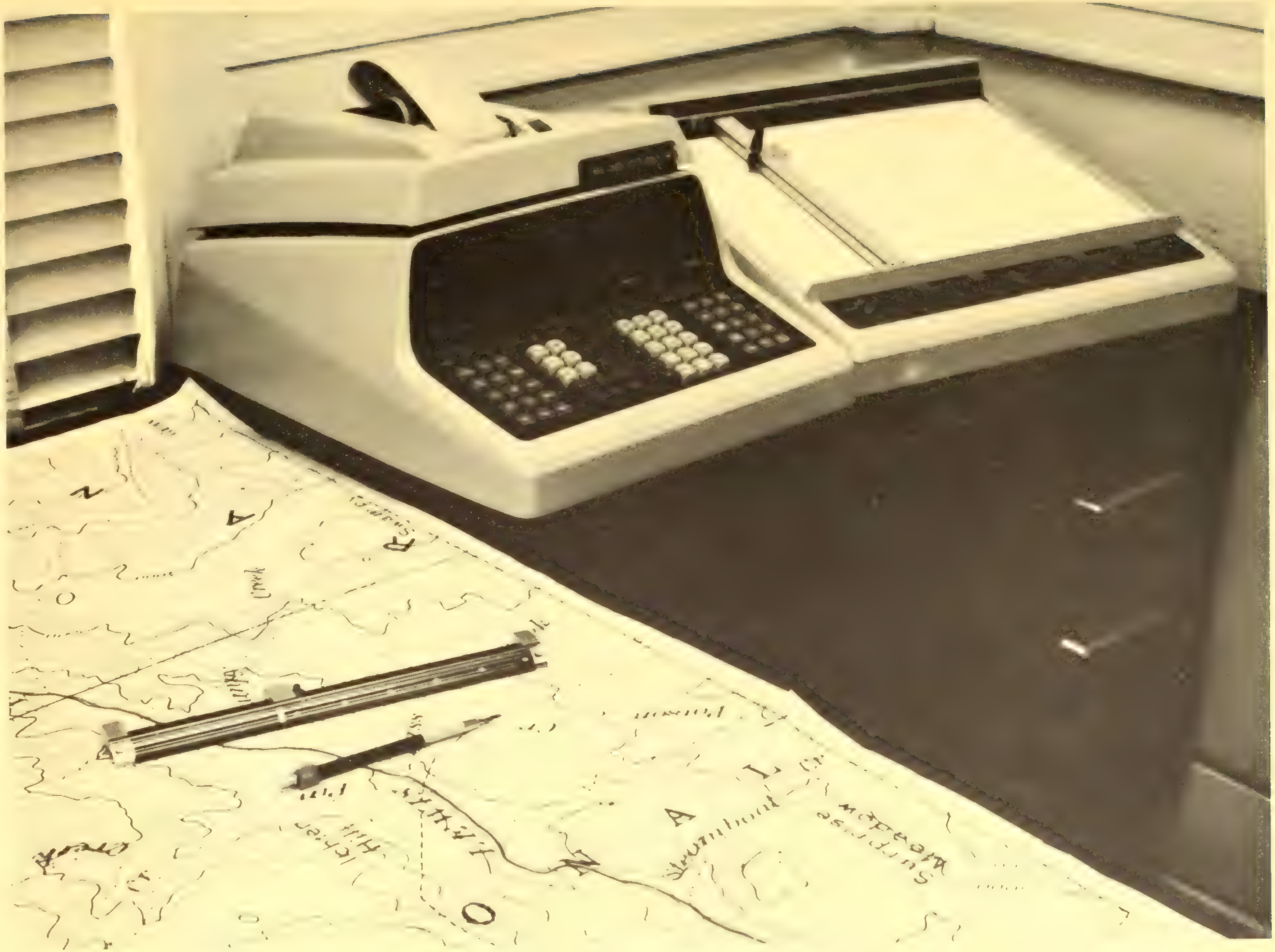

Figure 2.—Calculator, printer, and plotter combination.

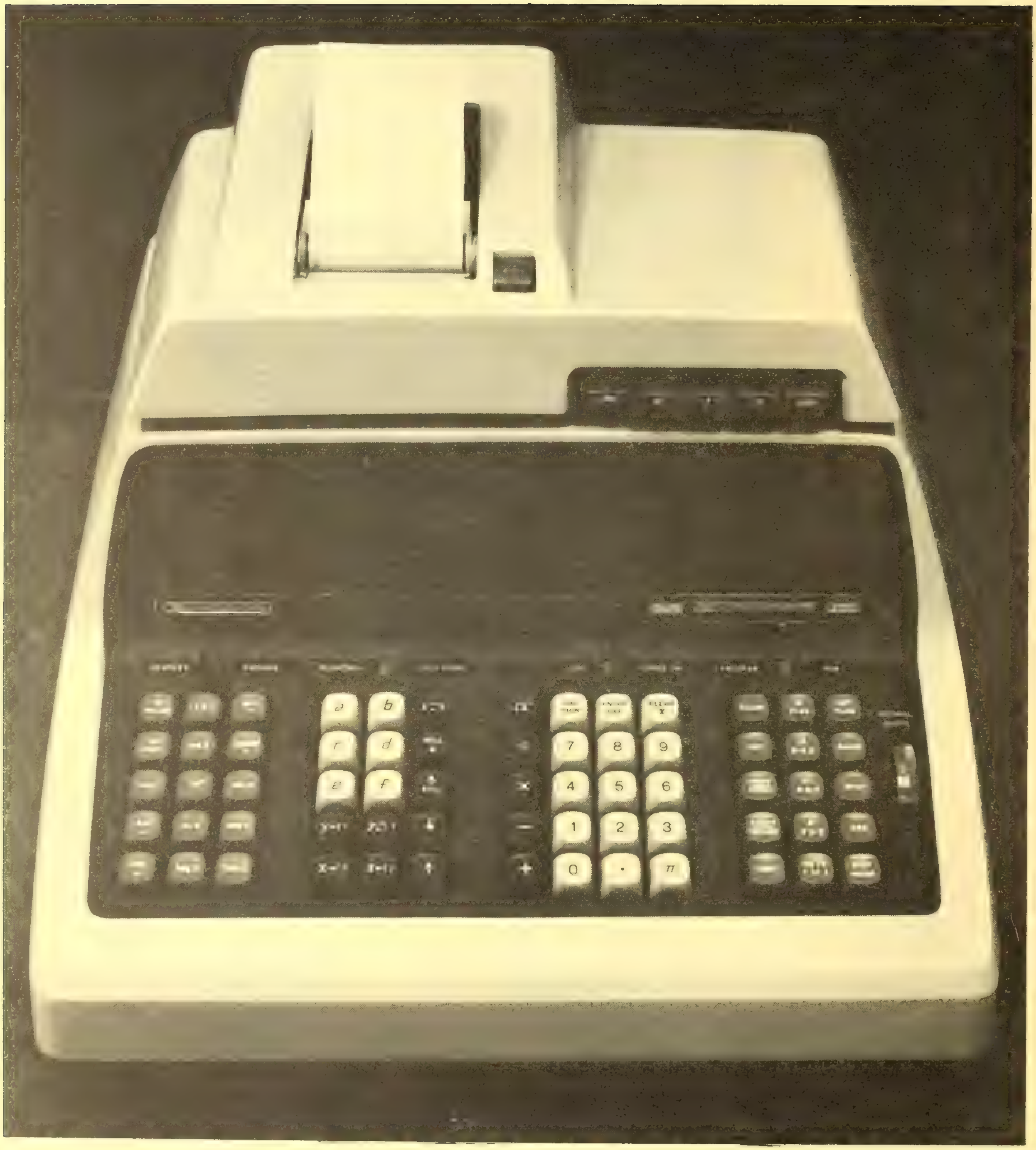

Figure 3.—Calculator keyboard.

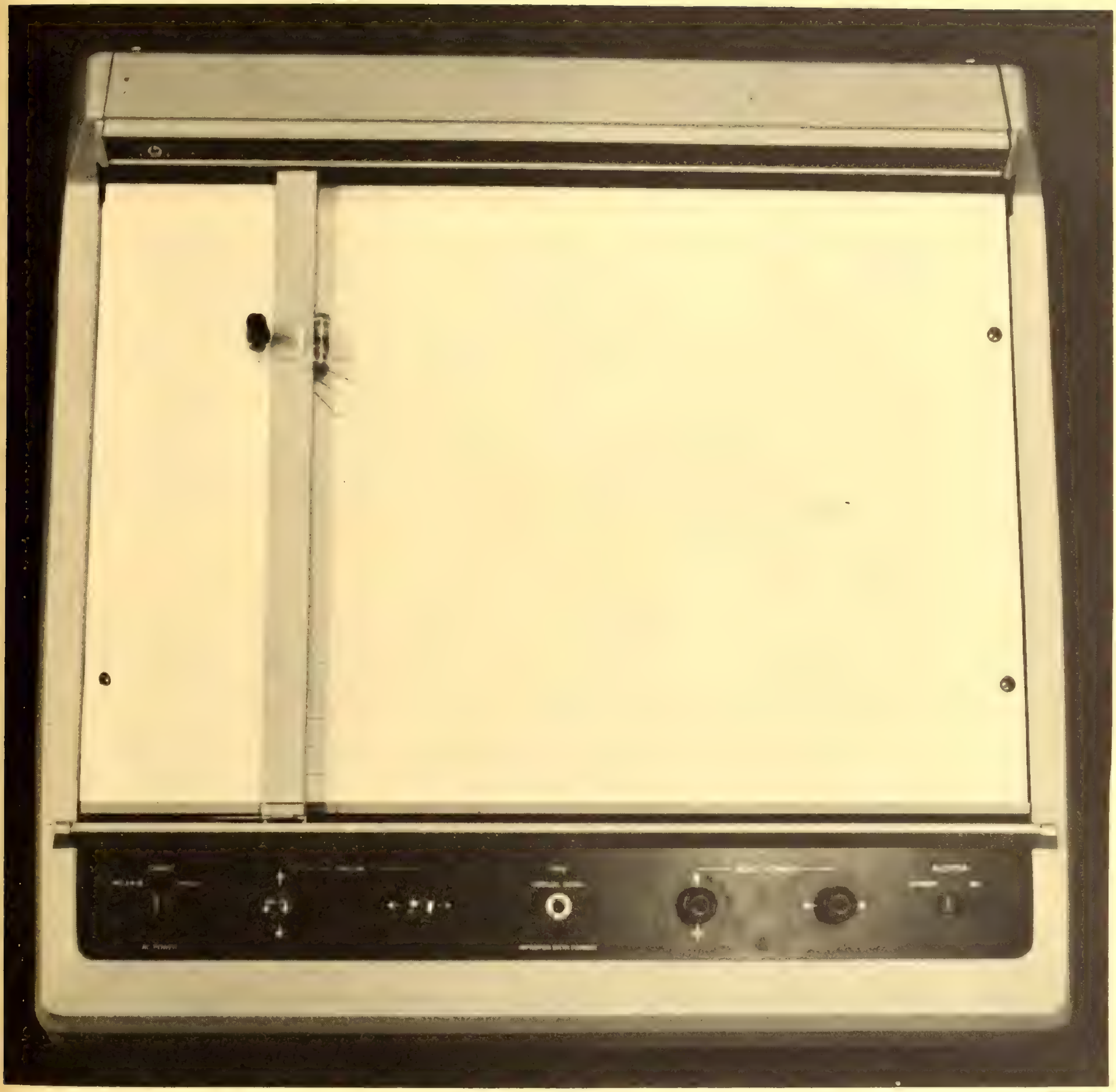

Figure 4.—Calculator plotter with sample output.

In general, the designer must establish his requirements for payload capability and ground clearance and determine whether the proposed equipment and ground profile will allow the path of the specified load to maintain the necessary clearance. An optimum design resulting from a first trial is highly improbable, but the designer's direct access to a desk-top computer makes it possible to quickly optimize by modifying the design.

An example will illustrate the problem. Consider a running skyline with 7/8-inch haulback, main, and grapple-opening lines. The span length is 800 feet, with a profile as indicated on the plot. The headspar is 50 feet tall, and the tailspar is 20 feet tall. Since in this example the logs are allowed to be yarded with one end on the ground, a minimum clearance of 10 feet is required below the load path. A payload of 10,000 pounds, to be supported by the skyline, is judged to be adequate considering that, in this example, one end of the load is supported by the ground. The carriage is assumed to weigh 1,000 pounds, which results in a gross payload requirement of 11,000 pounds.

4.0 PROBLEM SOLUTION

To solve the problem with a desk-top computer, the designer enters the station and elevation coordinates of terrain profile points and spar heights while the plotter, driven by the computer, plots the profile and the spars. Next, the designer enters the line weight, allowable tension, and a trial payload. The plotter traces the path of this load between the spar anchor points. At the same time, the computer shows the station and elevation coordinates of the load path. If the load path intersects the ground or fails to allow sufficient clearance, the designer can immediately test another load path with a lesser payload. The results may also indicate enough clearance to allow an increase in payload or the need to alter span length or location.

Figure 5 shows the solution of the hypothetical problem described earlier. A trial with an 11,000-pound gross payload provides a load path which clears all of the terrain points, with room to spare. A gross payload (log weight plus 1,000-pound carriage weight) of 25,000 pounds results in a carriage load path which comes within 10 feet of a terrain point. Therefore, this skyline road will allow a net payload of 24,000 pounds to be supported by the skyline. If the designer assumes that 40 percent of the log load is supported by the ground, the total log weight can be

$$W = \frac{24,000}{0.6} = 40,000 \text{ pounds.}$$

The load paths for the 11,000-pound and the 25,000-pound gross payloads are shown in figure 5.

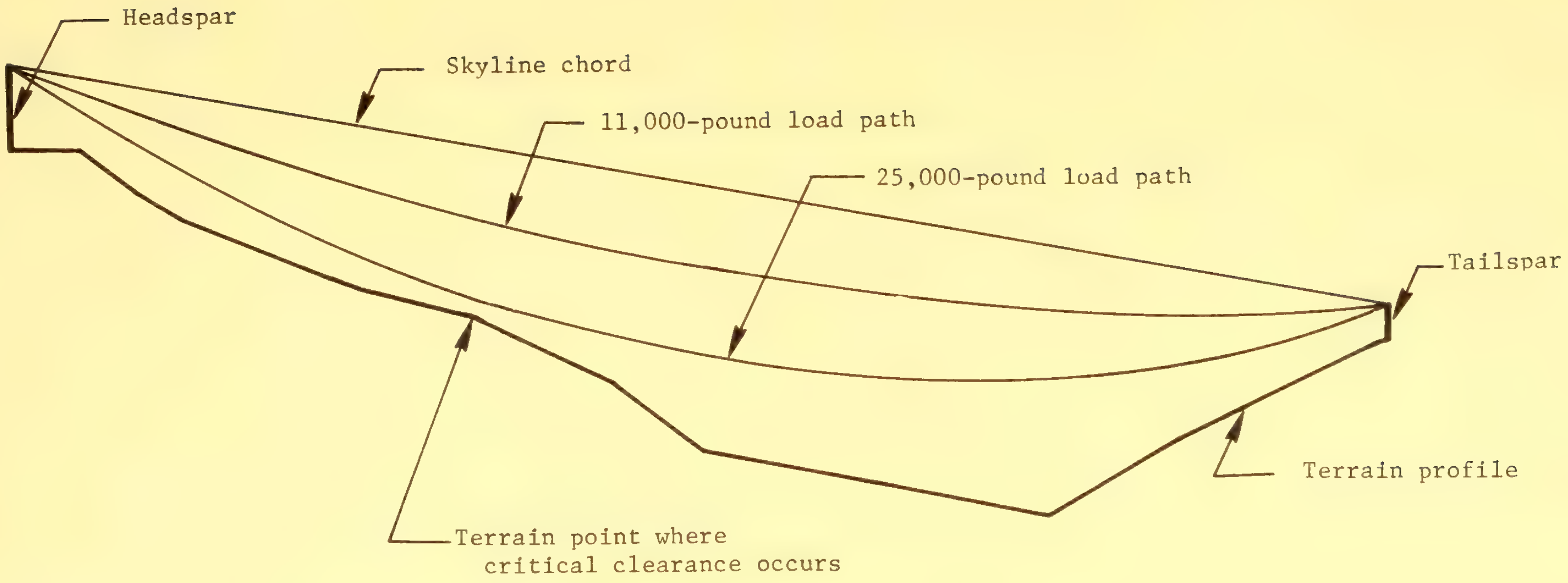

Figure 5.—Example of desk-top computer solution.

5.0 PROGRAMS FOR PROBLEM SOLUTION

A program for plotting the load path of the running skyline has been written for the Hewlett-Packard systems[6] from the force balance formulation discussed by Carson and Mann.[5] This program is used in conjunction with a profile plot program that was also written for the Hewlett-Packard system.

5.1 Profile Plot Program

This program will determine the scale of the plot, plot the ground profile, and plot the headspar, tailspar, and chord of the skyline.

The scale of the plot is determined by the computer from the span length and maximum ground elevation difference. It will choose the largest scale that will fit the 10-inch by 15-inch paper from the following:

Scale	Scale factor	x_{max}	Maximum ground elevation difference
1 inch = 50 feet	10	750 feet	450 feet
1 inch = 100 feet	5	1,500 feet	900 feet
1 inch = 200 feet	2.5	3,000 feet	1,800 feet
1 inch = 500 feet	1	7,500 feet	4,500 feet

The scale factors were computed from the plotter's scale factor of 500 counts per inch.

The operator can override the machine-selected scale factor by entering the program in the machine, entering the minimum elevation of the ground profile in the f register, entering the desired scale factor in the c register, and pressing Go To (3) (a). The program is then ready to accept x, y, and $HS1$ (see fig. 6).

Data needed to plot the profile are:

1. Maximum y_{max} and minimum y_{min} ground elevations.
2. Length of span (L).
3. Height of left, $HS1$, and right, $HS2$, spars.
4. Coordinates of terrain points in elevations and distance from the left spar tree (x, y).

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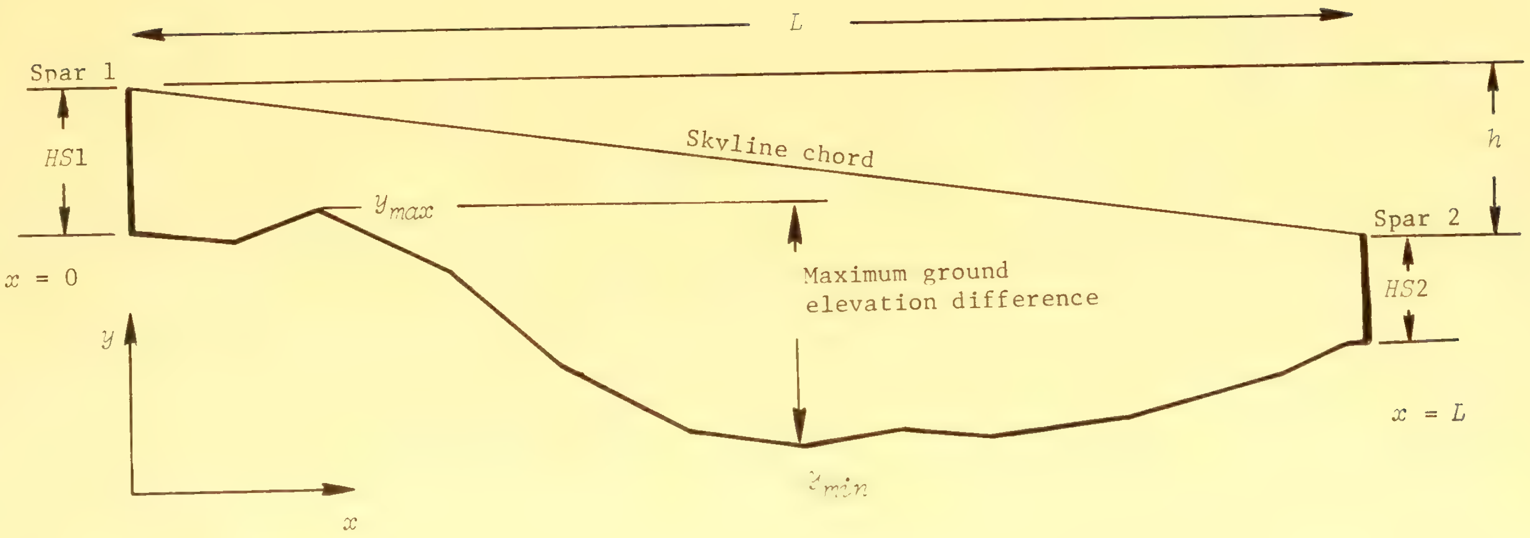
[6] The use of trade, firm, or corporation names in this publication is not an official endorsement or approval by the U. S. Department of Agriculture of any product to the exclusion of others which may be suitable.



$HS1$ = height of spar 1
$HS2$ = height of spar 2
L = length of span (feet)
y_{max} = highest ground elevation (feet)
y_{min} = lowest ground elevation (feet)
x = distance measured from spar 1 (or from first terrain point)
s = percent slope of chord
y = elevation of terrain point (feet)
h = anchor elevation difference (feet)

Figure 6.—Nomenclature of the profile plot program.

The output includes:

1. Scale factor (for use by the load path program).
2. Ground profile plot.
3. Headspar, tailspar, and chord of the skyline.
4. Percent slope of chord (up and to the right is positive slope).

If a ground profile plot is desired without the headspar, tailspar, and skyline chord, the program should be modified as follows:

1. Enter zero for height of left spar ($HS1$).
2. After last terrain point instead of pressing Go To (6) (0), press STOP. The span length (L) will now be the length of the profile, and the horizontal distance (x) will be measured from the first terrain point.

5.1.1 Profile Plot Program Flow

1. Input general dimensions:

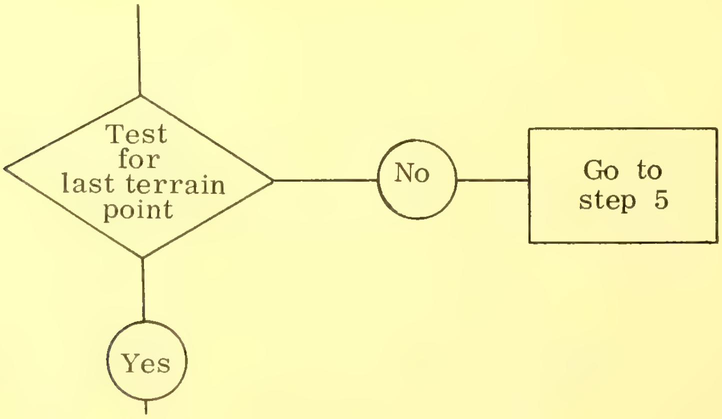
L = skyline span,

y_{max} = highest ground elevation,

and

y_{min} = lowest ground elevation.

2. Determine and print scale factor.
3. Enter coordinates of first terrain point and spar 1 height.
4. Determine coordinates of top of spar 1 and plot at first terrain point.
5. Enter coordinates of next terrain point.
6. Plot straight line to terrain point.
7.



8. Enter height of spar 2.
9. Plot spar 2 and skyline chord.
10. Determine and print chord slope in percent.

5.1.2 Profile Plot Program Operating Instructions

NOTE: Use the origin control to position the pen at the lower left corner of the paper.

Turn on Printer and x register key.

Enter program (starting address is +(0) (0)).

Press: CONTINUE.

Enter data:

L → z,

y_{max} → y,

and

y_{min} → x.

Press: CONTINUE.

Display:

SF - - - - - x.

Print: Scale factor.

Enter data:

$HS1$ → z, (Note: $HS1 = 0$ if the spar is not to be plotted.)

y → y,

and

x → x.

Press: CONTINUE.

Display:

x - - - - - - z.

Enter data: (Terrain points)

y → y,

x → x.

Press: CONTINUE.

Display:

x - - - - - - z,

SF(y) - - - y,

and

SF(x) - - - x.

After last terrain point is entered--

Press: Go To (6) (0).

Press: CONTINUE.

(Note: If the right spar ($HS2$) and the skyline chord are not to be plotted, press STOP.)

Enter data:

$HS2$ → x.

Press: CONTINUE.

Display:

0 - - - - - - z,

0 - - - - - - y,

and

Percent slope - - - - - x.

Print: Percent slope.

5.1.3 Profile Plot Program Listing

Step	Key	Code	Step	Key	Code	Step	Key	Code
00	CLR	20	40	e	12	80	e	12
01	STP	41	41	f	15	81	b	14
02	-	34	42	-	34	82	UP	27
03	AC+	60	43	c	16	83	f	15
04	4	04	44	X	36	84	X	36
05	5	05	45	0	00	85	UP	27
06	0	00	46	YTO	40	86	DN	25
07	0	00	47	d	17	87	c	16
08	XEY	30	48	FMT	42	88	X	36
09	DIV	35	49	DN	25	89	d	17
0a	YTO	40	4a	e	12	8a	+	33
0b	c	16	4b	RUP	22	8b	RDN	31
0c	RDN	31	4c	XTO	23	8c	XEY	30
0d	7	07	4d	e	12	8d	FMT	42
10	5	05	50	f	15	90	DN	25
11	0	00	51	-	34	91	e	12
12	0	00	52	c	16	92	UP	27
13	XEY	30	53	X	36	93	AC-	63
14	DIV	35	54	RUP	22	94	RCL	61
15	c	16	55	e	12	95	X>Y	53
16	X>Y	53	56	X	36	96	7	07
17	1	01	57	RDN	31	97	a	13
18	a	13	58	FMT	42	98	d	17
19	UP	27	59	DN	25	99	XEY	30
1a	1	01	5a	STP	41	9a	FMT	42
1b	0	00	5b	GTO	44	9b	DN	25
1c	X>Y	53	5c	4	04	9c	PSE	57
1d	2	02	5d	c	16	9d	FMT	42
20	4	04	60	XTO	23	a0	UP	27
21	GTO	44	61	b	14	a1	c	16
22	3	03	62	STP	41	a2	UP	27
23	7	07	63	RUP	22	a3	1	01
24	5	05	64	c	16	a4	0	00
25	X>Y	53	65	X	36	a5	0	00
26	2	02	66	RDN	31	a6	X	36
27	b	14	67	+	33	a7	DN	25
28	GTO	44	68	b	14	a8	PNT	45
29	3	03	69	FMT	42	a9	END	46
2a	7	07	6a	DN	25			
2b	2	02	6b	DIV	35			
2c	.	21	6c	RUP	22			
2d	5	05	6d	d	17			
30	X>Y	53	70	XEY	30			
31	3	03	71	DIV	35			
32	6	06	72	RDN	31			
33	GTO	44	73	-	34			
34	3	03	74	YTO	40			
35	7	07	75	c	16			
36	1	01	76	DN	25			
37	XTO	23	77	.	21			
38	c	16	78	8	10			
39	PNT	45	79	XTO	23			
3a	STP	41	7a	f	15			
3b	RDN	31	7b	.	21			
3c	+	33	7c	2	02			
3d	XTO	23	7d	XTO	23			

5.2 Load Path Plot

This program determines and plots the load path of the running skyline between supporting spars. The procedure of Carson and Mann[5] has been programed on the Hewlett-Packard 9100 Calculator, Printer, Plotter System. This program is designed to follow the profile plot program, although it can be run separately.

5.2.1 Load Path Plot Program Flow

(NOTE: This section contains symbols and equations discussed in Carson and Mann.[5])

1. Input skyline characteristics:

h = anchor elevation difference,

L = anchor span distance,

T_A = haulback allowable tension,

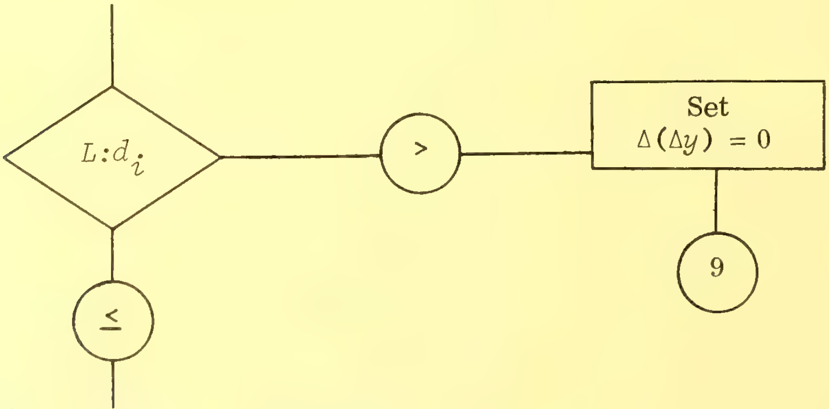
w_1 = haulback weight per foot,

and

w_3 = main and grapple-opening line weight per foot.

2. Input scale factor, SF.
3. Input gross payload weight, $(W_G)_{INPUT}$
4. Initialize -

   Set initial coordinates $(d,\ \Delta y)$ at $(0,0)$.
5. Establish Δd and determine $d_i = d_{i-1} + \Delta d$.
6.



7. Plot last point at L, h and STOP.
8. Prepare $\Delta(\Delta y) = L/100$ for second pass.
9. Prepare $(\Delta y)_{CHORD}$.

10. Determine new $\Delta y = (\Delta y)_{CHORD} + \Delta(\Delta y)$.

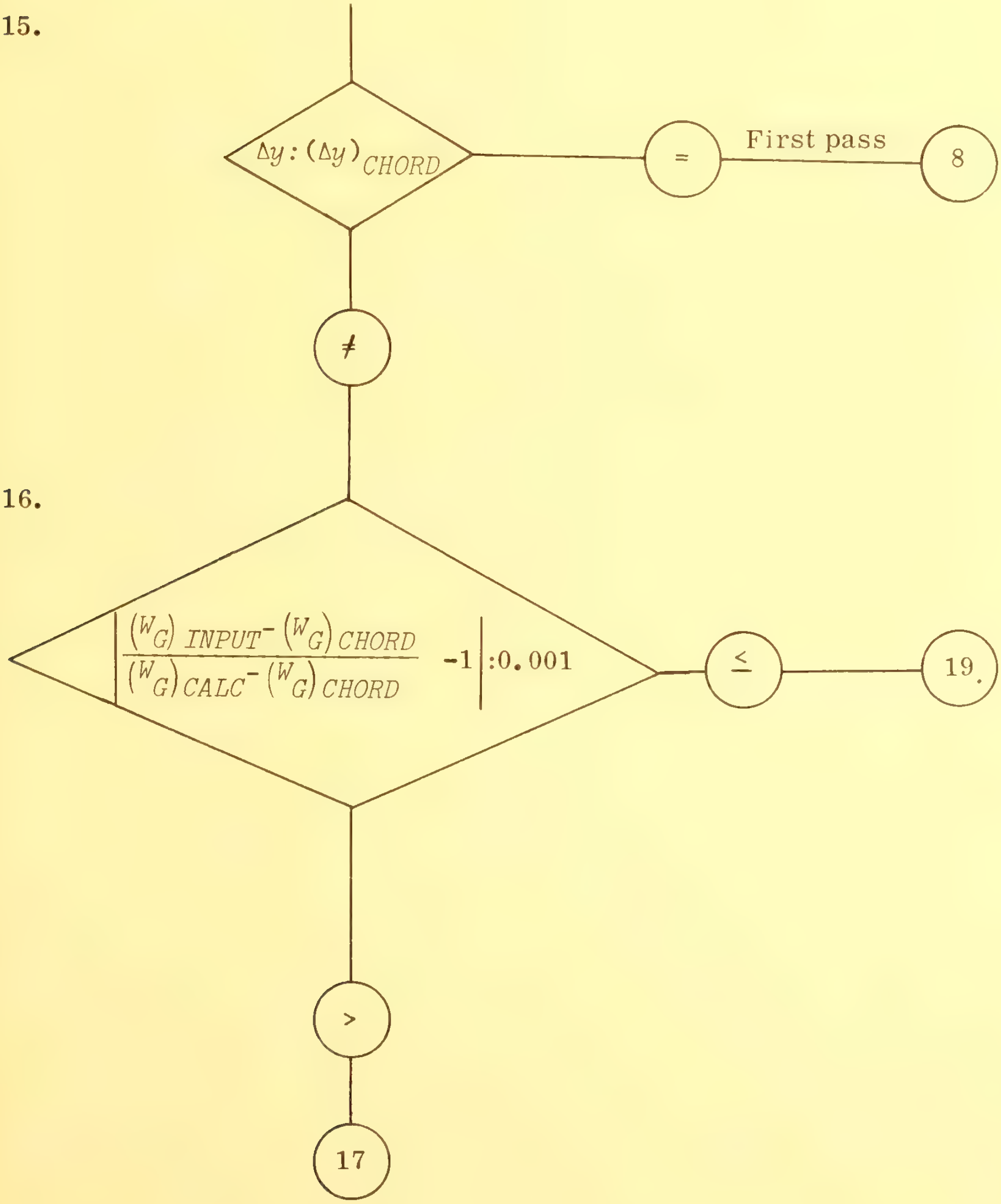
11. Determine V_1^1 and H_1 in a square root routine.

12. Determine V_2^2 and H_2 in a square root routine.

13. Determine V_s^2 and H_s.

14. Determine $(W_G)_{CALC}$.

15.


$\Delta y : (\Delta y)_{CHORD}$
=
First pass
8
≠
16.
$\left| \frac{(W_G)_{INPUT} - (W_G)_{CHORD}}{(W_G)_{CALC} - (W_G)_{CHORD}} - 1 \right| : 0.001$
≤
19.
>
17

17. Prepare $\Delta(\Delta y) = \{(\Delta y)_{CALC} - (\Delta y)_{CHORD}\} \left\{\dfrac{(W_G)_{INPUT} - (W_G)_{CHORD}}{(W_G)_{CALC} - (W_G)_{CHORD}}\right\}$

$$+ (\Delta y)_{CHORD}.$$

18. Go to step 9.

19. Prepare and plot (d, Δy) and return to step 5.

5.2.2 Load Path Plot Program Operating Instructions

NOTE: Press STOP and use the origin controls to locate the pen at the top of spar 1.

Turn on x in Printer.

Enter Program A: (starting address is +(0) (0)).

Enter Program B: (starting address is -(0) (0)).

Load:

SF = scale factor (same as profile plot) → a,

L = skyline span (same as profile plot) → b,

h = anchor elevation difference (see fig. 6) → c,

w_3 = weight per foot of main and operating line → +9,

w_1 = weight per foot of haulback → +8,

T_A = operating tension (usually one-third of haulback breaking strength) → +7.

Press: END (or Go To +(0) (0)).

Enter: W_G, gross payload (combined log and carriage weight) → x.

Press: CONTINUE.

If the plot of more than one gross payload is desired, repeat the last three steps.

5.2.3 Load Path Program Listing

Load Path - Page

```
00  CHS  32      40  c    16      80  X>Y  53
01  XEY  30      41  UP   27      81  9    11
02  b    14      42  b    14      82  3    03
03  +    33      43  CHS  32      83  c    16
04  EEX  26      44  AC+  60      84  XEY  30
05  2    02      45  RCL  61      85  b    14
06  DIV  35      46  CHS  32      86  DIV  35
07  RUP  22      47  XTO  23      87  f    15
08  XTO  23      48  f    15      88  X    36
09  4    04      49  POL  62      89  e    12
0a  f    15      4a  1    01      8a  XEY  30
0b  XEY  30      4b  RCT  66      8b  -    34
0c  b    14      4c  XEY  30      8c  RDN  31
0d  DIV  35      4d  RDN  31      8d  X    36

10  c    16      50  DIV  35      90  GTO  44
11  X    36      51  YTO  40      91  1    01
12  DN   25      52  5    05      92  2    02
13  +    33      53  DN   25      93  GTO  44
14  YTO  40      54  X    36      94  +    33
15  e    12      55  UP   27      95  1    01
16  XFR  67      56  RCL  61      96  9    11
17  7    07      57  POL  62      97  UP   27
18  SFL  54      58  XEY  30      98  X    36
19  GTO  44      59  XFR  67      99  UP   27
1a  SUB  77      5a  9    11      9a  RCL  61
1b  9    11      5b  X    36      9b  POL  62
1c  7    07      5c  2    02      9c  XEY  30
1d  XTO  23      5d  DIV  35      9d  XFR  67

20  5    05      60  DN   25      a0  8    10
21  YTO  40      61  -    34      a1  X    36
22  6    06      62  XFR  67      a2  2    02
23  POL  62      63  6    06      a3  DIV  35
24  UP   27      64  +    33      a4  YTO  40
25  c    16      65  XFR  67      a5  -    34
26  UP   27      66  4    04      a6  e    12
27  b    14      67  UP   27      a7  DN   25
28  AC-  63      68  CLX  37      a8  UP   27
29  f    15      69  X=Y  50      a9  X    36
2a  CHS  32      6a  0    00      aa  RDN  31
2b  XTO  23      6b  2    02      ab  -    34
2c  f    15      6c  d    17      ac  YTO  40
2d  RUP  22      6d  XEY  30      ad  -    34

30  GTO  44      70  -    34
31  SUB  77      71  XEY  30
32  9    11      72  RDN  31
33  7    07      73  -    34
34  YE   24      74  RDN  31
35  5    05      75  DIV  35
36  +    33      76  UP   27
37  +    33      77  DN   25
38  YE   24      78  1    01
39  6    06      79  -    34
3a  DN   25      7a  |Y|  55
3b  -    34      7b  EEX  26
3c  DN   25      7c  3    03
3d  +    33      7d  CHS  32
```

-Page cont'd.

Step	Key	Code	x	y	z
b0	f	15			
b1	RCL	61			
b2	DIV	35			
b3	DN	25			
b4	X	36			
b5	UP	27			
b6	X	36			
b7	1	01			
b8	+	33			
b9	RUP	22			
ba	IFG	43			
bb	ARC	72			
bc	CHS	32			
bd	RUP	22			
c0	DIV	35			
c1	UP	27			
c2	XFR	67			
c3	-	34			
c4	f	15			
c5	XEY	30			
c6	DIV	35			
c7	DN	25			
c8	RDN	31			
c9	X	36			
ca	RDN	31			
cb	+	33			
cc	DN	25			
cd	SQR	76			
d0	+	33			
d1	RUP	22			
d2	RCL	61			
d3	DIV	35			
d4	DN	25			
D5	X	36			
d6	XFR	67			
d7	-	34			
d8	e	12			
d9	-	34			
da	DN	25			
db	SUB	77			

Storage			
0		8	
1		9	
2		a	
3		b	
4		c	
5		d	
6		e	
7		f	

Load Path + Page

00	XTO	23
01	d	17
02	PNT	45
03	CLR	20
04	FMT	42
05	DN	25
06	b	14
07	XEY	30
08	1	01
09	0	00
0a	DIV	35
0b	DN	25
0c	AC+	60
0d	f	15
10	UP	27
11	b	14
12	X>Y	53
13	3	03
14	0	00
15	c	16
16	XTO	23
17	e	12
18	SFL	54
19	RCL	61
1a	UP	27
1b	XFR	67
1c	5	05
1d	PNT	45
20	a	13
21	X	36
22	RUP	22
23	X	36
24	CLX	37
25	RDN	31
26	CHS	32
27	XEY	30
28	IFG	43
29	3	03
2a	4	04
2b	GTO	44
2c	0	00
2d	4	04
30	GTO	44
31	-	34
32	0	00
33	0	00
34	FMT	42
35	DN	25
36	CLR	20
37	FMT	42
38	UP	27
39	END	46

0		8	
1		9	
2		a	
3		b	
4		c	
5		d	
6		e	
7		f	

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SELECTED 1966-69 INTERIOR ALASKA WILDFIRE STATISTICS WITH LONG-TERM COMPARISONS

by

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ABSTRACT

This paper presents selected interior Alaska forest and range wildfire statistics for the period 1966-69. Comparisons are made with the decade 1956-65 and the 30-year period 1940-69, which are essentially the total recorded statistical history on wildfires available for Alaska.

Keywords: Forest fires, range burning, Alaska.

INTRODUCTION

The purpose of this paper is to summarize and coordinate the most recent period and the past three decades of wildfire activity for interior Alaska.[1] Formal records on interior Alaska wildfires in summarized form became available about 1940. Throughout the past three decades, records and recording procedures have changed as have other activities in the wildfire control. Previous publications

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[1] Interior Alaska is essentially defined as that portion south of the Brooks Range, excluding the "panhandle" and Aleutian chain.

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have covered Alaskan wildfire statistics in detail through 1965.[2] [3] The period 1966-69 was selected for this summary because it completes the third decade since records of this type have been assembled. Wildfire and its impact in Alaska's interior are becoming more important as concern and interest in the northern environment increase.

We now have wildfire data covering the decades of the forties, fifties, and the sixties for the interior of Alaska. The 1966-69 data have been previously summarized, however, only in office reports which are generally unavailable to the public. Additionally, the period 1966-69 was one of extremely high fire activity as indicated in the tables by the numbers and acreage burned. Information summarized is a continuing attempt to provide more useful background material for reference in wildland resource management protection and utilization.

FIRE OCCURRENCE

During the 1966-69 period, 1,417 forest and range fires burned in Alaska's interior. The number of fires occurring in these four years was slightly over half the earlier 10-year total of 2,178 fires. The ratio of lightning-caused fires to man-caused fires for the 4-year period is generally comparable to the preceding decade of 1956-65; however, the average annual number of fires was up considerably. Tables 1-5 are provided in the same format as tables in a previous publication (see footnote 3) which allows easy direct comparison of these data.

In the monthly fire occurrence history for the 1966-69 period (fig. 1), the characteristic peak occurs during midsummer for the lightning-caused fire category. However, some deviation from the previous data is evident for man-caused fires, which peak in May, as recorded in earlier reports, but the decline is not as rapid as experienced in the preceding decade. Lightning-caused fires, on the other hand, reached their peak 1 month later than reported previously. This situation in part is a reflection of the protracted fire seasons during the 1966-69 period. In respect to the 30-year summaries, (1940-69), a June peak for the lightning-caused fire occurrence still is most representative of long-term trends.

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[2] Charles E. Hardy and James W. Franks. Forest fires in Alaska. Ogden, Utah, Intermountain Forest & Range Exp. Sta. USDA Forest Serv. Res. Pap. INT-5, 163 p., illus., 1963.

[3] Richard J. Barney. Interior Alaska wildfires, 1956-1965. Juneau, Alaska, USDA Forest Serv. Pac. Northwest Forest & Range Exp. Sta., Inst. N. Forest., 47 p., illus., 1969.

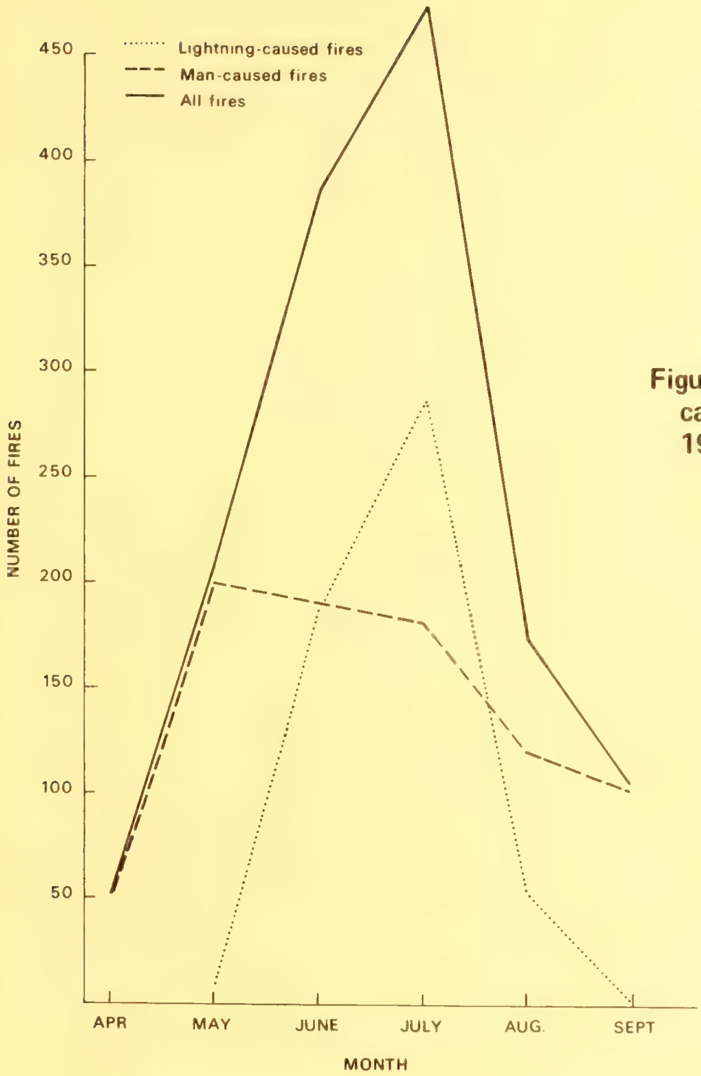

Figure 1.—Total number of fires by cause and month, interior Alaska, 1966-69.

AREA BURNED

As table 1 indicates, 6,206,977 acres burned during the 1966-69 period. The most recent 4 years almost equaled the preceding 10 years in terms of acreage blackened by wildfire. The average for acres burned per fire is higher in the "All" fire category as well as the lightning-caused fire category, compared with the preceding decade. This is also true of the man-caused fires; however, the difference is perhaps much more startling since the increase is greater than 800 percent. The average size for lightning-caused fires during the last 4 years was approximately 8,805 acres per fire. The annual number of fires has also risen considerably above the 1956-65 average of 218 in all years except 1967. Lightning-caused fires continued to burn the largest percentage of the total acreage. This point was accentuated during the 1968 and 1969 seasons because so many fires were left to burn without control, having been classed as economically inaccessible for fire control action by the Bureau of Land Management.

Wildfire distribution by size class[4] as indicated in table 2 shows the same type of relationships continue as were portrayed in the data from the previous 10-year period. The majority of man-caused fires fall into the Class A category, whereas lightning-caused fires fall most often in Class B, with Class E running a close second. More than 80 percent of all man-caused fires fall into Class A or B size class and over 90 percent are held or controlled to Class C or smaller. This relationship does not hold in respect to the lightning-caused fires. The size-class distribution differences between lightning-caused fires and man-caused fires again can probably be attributed to differences of detection time and travel time from the headquarter's attack station to the fire, as well as the lower resource value classes and resultant lack of action on many of the more distant interior fires.

FIRE DANGER RATING

Table 3 shows fire occurrence as experienced by various classes of spread index and buildup index based on the National Fire Danger Rating System. The index value used of necessity was the value from the closest or most "representative" station for the day of fire start. One caution is that the fire could have burned for several weeks or even months. The distributions are relative indicators of relationships and show general trends.

Frequency distributions of the buildup index and fires are quite similar to those portrayed in earlier summaries. More than 80 percent of the acreage burned occurred above a buildup index of 80, and 40 percent of fire starts occurred above that same buildup-index level. Over 40 percent of acreage burned when the spread index was higher than 40, and a shift in fire incidence was demonstrated at the higher spread-index levels compared with the previous 10-year periods. More fires occurred at both higher buildup-index and spread-index levels than had been recorded during the previous 10-year period. As an example, eight fires occurred at a buildup index of 200 and higher and 56 fires occurred above the spread index of 70 with six fires occurring in the 90-100 category. Again, as pointed out earlier, the large acreage burned and number of starts at the lower index levels is attributed to the fact that many of the fires starting earlier in the season were allowed to continue burning throughout the season until they went out naturally. These same fires accounted for a large percentage of the acreage burned.

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[4] Classes are: A, 1/4 acre or less; B, 1/4 acre to 10 acres; C, 10 to 100 acres; D, 100 to 300 acres; E, 300 acres and larger.

For other comparisons, tables 4 and 5 indicate fire statistics summaries by Bureau of Land Management districts and administrative areas. In addition, these tables provide a general view of the fire problem and distribution on a more regional basis rather than the interior as a whole. On a district basis,[5] the Fairbanks District has the dubious honor of accounting for approximately 10 times more acreage burned during the 4-year period than the Anchorage District. At the same time, the number of fires was in many respects quite similar between districts, differing only by approximately 100 fires. Figure 2 shows the resource area boundary locations.

THE 30-YEAR PERIOD

In combining the 30-year fire statistics from available sources,[6] we find that annual fire incidence ranges from a low of 53 fires per year, which was experienced in 1949, to a high of 512 fires in 1969. The peak in man-caused fire occurrence was in 1969, compared with 1968 for lightning-caused fires. The smallest number of man-caused fires was reported as far back as 1949 which coincides with the minimum total number of fires. No lightning-caused fires were reported in 1940, 1941, and 1942. Doubtless, lightning was occurring during this period; however, detection and reporting procedures apparently did not account for any.

The shifts in annual numbers of fires, the changing ratios of man-caused to lightning-caused fires, and many of the other variations surrounding fire statistical summaries are in part a function of improved technology. These improvements include changing detection methods, changing suppression capabilities, and changing prevention methods. Therefore, it is difficult to normalize fire statistics over a long-term period. We may, however, generalize from the long-term

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[5] The Fairbanks District is comprised of four administrative areas, Arctic, Delta, Fairbanks, and Koyukuk; the Anchorage District is comprised of five management units, Bristol Bay, Cook Inlet, Glenallen, McGrath, and Southeast.

[6] See footnotes 2 and 3.

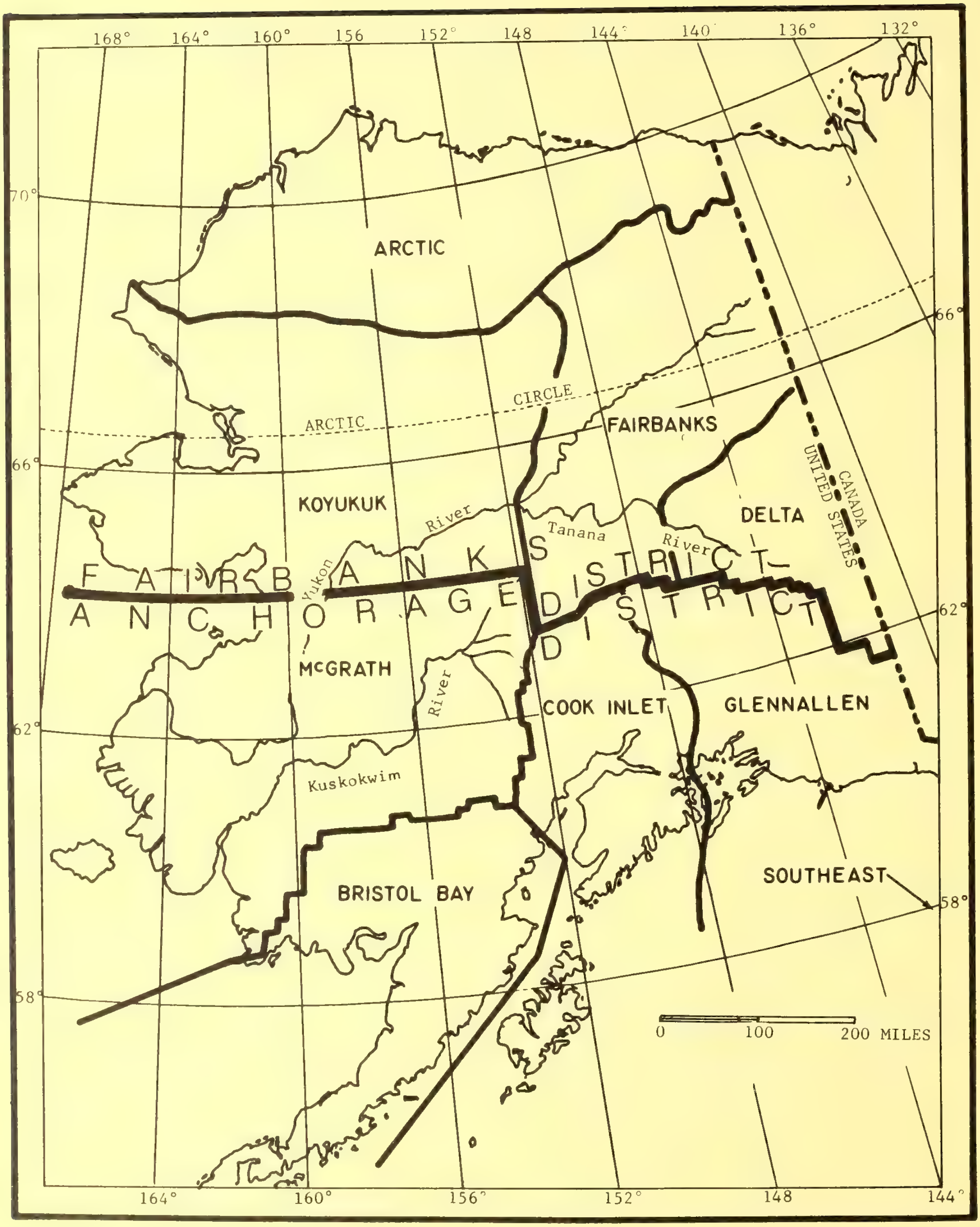

Figure 2.—Map of interior Alaska showing Bureau of Land Management administrative areas as used for sorting data.

trends. It is interesting to note that if we exclude the period of 1940, 1941, and 1942, the general ratio between man-caused and lightning-caused fires ranges between 60 and 80 percent man-caused with the balance being lightning-caused. There are some exceptions, and in 1 or 2 years a reversal of the ratio exists. However, this percentage relationship or ratio is really quite consistent. It is hard to say with certainty whether or not we are experiencing more fires now than we did in the past. This is especially questionable for man-caused fires. Part of this problem is attributed to quicker reporting today and changes in reporting criteria and rules. Part of it is perhaps attributable to our past and present inability to detect all fires and then to classify them properly as to real cause.

Data as presented are the best available and do provide a valuable benchmark by which we may generalize and assess the fire history of an area. Acreage burned over from the 1950 period on is perhaps of most interest. It is the opinion of several fire control people that the accuracy of acreage figures are much better for the decades of the fifties and sixties than during the preceding period. Here again, this is a function of capability of the organization to make such assessments. Table 6 as well as figure 3 illustrate the 1940-69 long-term trends for comparative purposes and more specific appraisal by the reader.

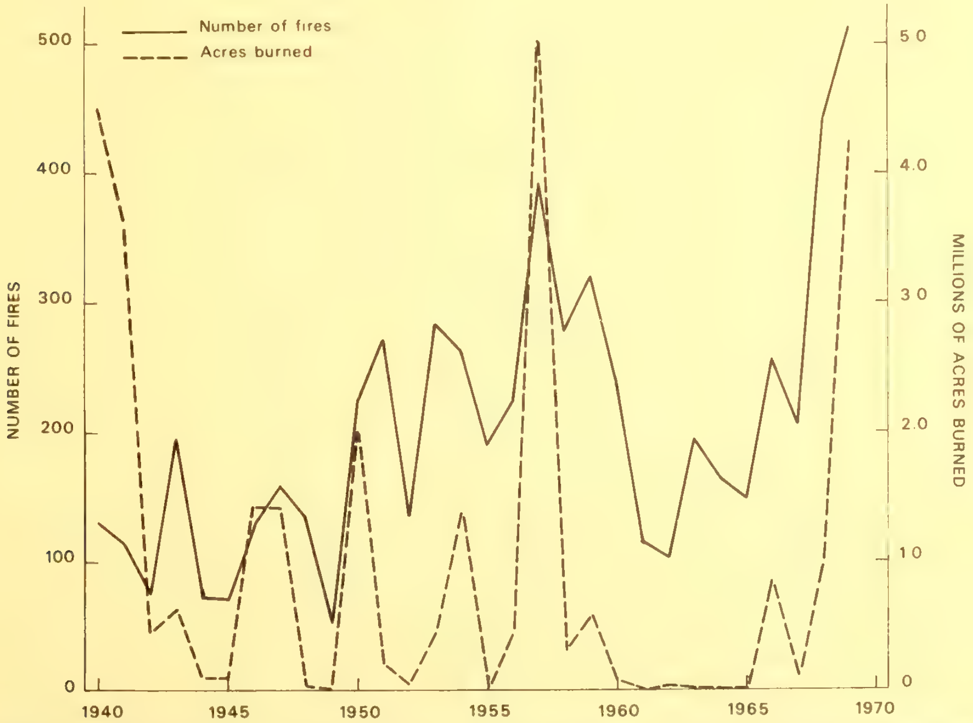

Figure 3.—Number of fires and acres burned in interior Alaska, 1940-69.

SUMMARY

It is hoped that the material presented in this paper coupled with fire statistics mentioned in the previously footnoted sources will assist fire control, fire research, and interested individuals with some of the basic historical information relative to wildfires in the interior of Alaska. As we enter the seventies, a new awareness and concern about the natural environment exists. There is also a new philosophy and capability in fire control itself.

Table 1.--*Number of fires, total acres burned, and acres burned per fire, by cause, and percent, interior Alaska, 1966-69*

Year	Lightning-caused fires					Man-caused fires					All fires		
	Number	Percent of all fires	Acres burned			Number	Percent of all fires	Acres burned			Number	Acres per fire	Total acres
			Per fire	Total	Percent of total for all fires			Per fire	Total	Percent of total for all fires			
1966	74	28.9	11,368	841,266	98.6	182	71.1	64	11,694	1.4	256	3,332	852,960
1967	73	35.3	1,427	104,162	95.6	134	64.7	36	4,843	4.4	207	527	109,005
1968	63	59.5	3,836	1,008,991	99.6	179	40.5	24	4,310	.4	442	2,293	1,013,301
1969	125	24.4	22,049	2,756,169	65.1	387	75.6	3,813	1,475,542	34.9	512	8,265	4,231,711
Total or average	535	37.8	8,805	4,710,588	75.9	882	62.2	1,697	1,496,389	24.1	1,417	4,380	6,206,977

Table 2.--*Number and percent of fires by size class and cause, interior Alaska, 1966-69*

Size class[1]	1966		1967		1968		1969		Total	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
LIGHTNING-CAUSED FIRES										
A	3	4	9	12	24	9	7	6	43	8
B	30	40	19	26	90	34	31	25	170	32
C	22	30	16	22	55	21	26	21	119	22
D	7	10	7	10	16	6	2	1	32	6
E	12	16	22	30	78	30	59	47	171	32
Total	74	100	73	100	263	100	125	100	535	100
MAN-CAUSED FIRES										
A	77	42	65	48	91	51	181	46	414	47
B	79	44	51	38	66	37	131	34	327	37
C	15	8	13	10	13	7	38	10	79	9
D	6	3	1	1	6	3	15	4	28	3
E	5	3	4	3	3	2	22	6	34	4
Total	182	100	134	100	179	100	387	100	882	100
TOTAL FIRES										
A	80	31	74	36	115	26	188	37	457	32
B	109	43	70	34	156	35	162	32	497	35
C	37	14	29	14	68	16	64	12	198	14
D	13	5	8	4	22	5	17	3	60	4
E	17	7	26	12	81	18	81	16	205	15
Total	256	100	207	100	442	100	512	100	1,417	100

[1] A, 1/4 acre or less; B, 1/4 acre to 10 acres; C, 10 to 100 acres; D, 100 to 300 acres; E, 300 acres and larger.

Table 3.--*Number and percent of fires and acres burned, by buildup-index and spread-index classes, interior Alaska, 1966-69*

Buildup index					Spread index				
Index class	Fires		Acres burned		Index class	Fires		Acres burned	
	Number	Percent	Number	Percent		Number	Percent	Number	Percent
0-19	85	6.4	2,193	<0.1	0-9	22	1.7	1,261	<0.1
20-39	194	14.7	117,907	1.9	10-19	89	6.7	226,735	3.7
40-59	247	18.8	502,192	8.1	20-29	299	22.7	587,408	9.5
60-79	264	20.1	592,633	9.6	30-39	412	31.2	2,888,012	46.7
80-99	225	17.1	1,726,327	27.9	40-49	238	18.1	908,756	14.7
100-119	121	9.1	667,709	10.8	50-59	145	11.0	1,549,261	25.1
120-139	87	6.6	986,882	16.0	60-69	57	4.3	12,225	.2
140-159	56	4.3	917,726	14.9	70-79	29	2.2	4,598	<.1
160-179	20	1.5	543,891	8.8	80-89	21	1.6	109	<.1
180-199	11	.8	113,763	1.8	90-100	6	.5	239	<.1
200-219	4	.3	4,352	<.1					
220+	4	.3	3,029	<.1					
Total[1]	1,318	100.0	6,178,604	100.0	Total[1]	1,318	100.0	6,178,604	100.0

[1] The table shows 99 fewer fires and 28,373 fewer acres burned than shown in other tables due to missing fire danger data on some fire reports.

Table 4.--Fire statistics summary by administrative area, Anchorage District, 1966-69

Area	Number of fires by size class[1/]					Total number of fires	Number of fires by cause		Acres burned by cause		Total acres burned
	A	B	C	D	E		Man-caused fires	Lightning-caused fires	Man-caused fires	Lightning-caused fires	
Bristol Bay	1	5	0	3	3	12	10	2	2,459	30	2,489
Cook Inlet	109	131	28	13	9	290	283	7	88,197	1,839	90,036
Glennallen	86	40	8	0	3	137	128	9	5,167	176	5,343
McGrath	23	76	47	14	38	198	45	153	57,374	349,942	407,316
Southeast	24	2	0	0	0	26	26	0	<1	0	0
District total	243	254	83	30	53	663	492	171	153,197	351,987	505,184

[1/] A, 1/4 acre or less; B, 1/4 to 10 acres; C, 10 to 100 acres; D, 100 to 300 acres; E, 300 acres and larger.

Table 5.--Fire statistics summary by administrative area, Fairbanks District, 1966-69

Area	Number of fires by size class[1/]					Total number of fires	Number of fires by cause		Acres burned by cause		Total acres burned
	A	B	C	D	E		Man-caused fires	Lightning-caused fires	Man-caused fires	Lightning-caused fires	
Arctic	0	0	0	0	0	0	0	0	0	0	0
Delta	63	47	25	3	28	166	107	59	632,166	925,628	1,557,794
Fairbanks	140	155	51	17	47	410	266	144	710,314	554,847	1,265,161
Koyukuk	11	41	39	10	77	178	17	161	712	2,878,126	2,878,838
District total	214	243	115	30	152	754	390	364	1,343,192	4,358,601	5,701,793

[1/] A, 1/4 acre or less; B, 1/4 to 10 acres; C, 10 to 100 acres; D, 100 to 300 acres; E, 300 acres and larger.

Table 6.--Number of fires and acres burned by cause, interior Alaska, 1940-69[1]

ear	Lightning-caused				Man-caused				Total	
	Fires		Acres		Fires		Acres		Fires	Acres
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	
940	0	0	--	--	130	100	--	--	130	4,500,000
941	0	0	--	--	116	100	--	--	116	3,645,774
942	0	0	--	--	78	100	--	--	78	452,510
943	40	20.6	--	--	154	79.4	--	--	194	666,773
944	18	24.6	--	--	55	75.4	--	--	73	110,604
945	30	42.2	--	--	41	57.8	--	--	71	117,313
946	52	40.0	--	--	78	60.0	--	--	130	1,436,597
947	32	20.1	--	--	127	79.9	--	--	159	1,429,896
948	21	15.7	--	--	113	84.3	—	--	134	33,676
949	7	13.2	--	--	46	86.8	--	--	53	17,933
otal	200	17.6	--	--	938	82.4	--	--	1,138	12,411,076
verage	20				94				114	1,241,108
1950	27	12.0	445,595	21.6	197	88.0	1,612,222	78.4	224	2,057,817
1951	27	10.0	17,484	8.0	244	90.0	202,210	92.0	271	219,694
1952	11	8.1	14,556	19.7	125	91.9	59,245	80.3	136	73,801
1953	75	26.3	381,143	81.6	210	73.7	85,605	18.4	285	466,748
1954	63	24.0	1,347,990	97.0	199	76.0	41,930	3.0	262	1,389,920
1955	26	13.7	10,467	28.1	164	86.3	26,765	71.9	190	37,232
1956	64	28.0	446,746	94.0	162	72.0	29,847	6.0	226	476,593
1957	160	41.0	5,029,081	99.0	231	59.0	20,915	1.0	391	5,049,996
1958	92	33.0	228,648	72.0	186	67.0	88,567	28.0	278	317,215
1959	200	62.0	580,830	97.0	130	38.0	15,744	3.0	320	596,574
Total	745	25.8	8,502,540	61.8	1,838	74.2	2,183,050	38.2	2,583	10,685,590
Average	74		850,254		184		218,305		258	1,068,559
1960	62	26.0	32,657	37.0	176	74.0	54,523	63.0	238	87,180
1961	31	26.0	1,283	25.0	86	74.0	3,817	75.0	117	5,100
1962	53	52.0	37,828	97.0	49	48.0	1,147	3.0	102	38,975
1963	79	41.0	13,859	85.0	115	59.0	2,431	15.0	194	16,290
1964	63	38.0	2,430	71.0	101	62.0	1,000	29.0	164	3,430
1965	30	20.0	2,918	41.0	118	80.0	4,175	59.0	148	7,093
1966	74	28.9	841,266	98.6	182	71.1	11,694	1.4	256	852,960
1967	73	35.3	104,162	95.6	134	64.7	4,843	4.4	207	109,005
1968	263	59.5	1,008,991	99.6	179	40.5	4,310	0.4	442	1,013,301
1969	125	24.5	2,756,169	65.1	387	75.5	1,475,542	34.9	512	4,231,711
Total	853	35.1	4,801,563	71.7	1,527	64.9	1,563,482	28.3	2,380	6,365,045
Average	85		480,156		153		156,348		238	636,504
1940-69 Total	1,798	29.5	13,304,103[2]	78.0[2]	4,303	70.5	3,746,532[2]	22.0[2]	6,101	29,461,711
Average	60		665,205[2]		143		187,326[2]		203	982,057

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[1] Sources: Data for 1940-55 taken from Charles E. Hardy and James W. Franks. Forest fires in Alaska. Ogden, Utah, Intermountain Forest & Range Exp. Sta. USDA Forest Serv. Res. Pap. INT-5, 163 p., illus., 1963.

Data for 1956-65 taken from Richard J. Barney. Interior Alaska wildfires, 1956-65. Juneau, Alaska, USDA Forest Serv. Pac. Northwest Forest & Range Exp. Sta., Inst. N. Forest., 47 p., illus., 1969.

Data for 1966-69 taken from Bureau of Land Management fire reports.

[2] 1950-69 only. Total acres burned during these years, 17,050,635.

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USDA FOREST SERVICE RESEARCH NOTE

PNW-155 *July 1971*

EFFECT OF PONDEROSA PINE NEEDLE LITTER ON GRASS SEEDLING SURVIVAL

NOV 22 1971

by

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and

Justin G. Smith, *Principal Plant Ecologist*

ABSTRACT

Hard fescue survival rates were followed for 6 years on four different pine needle treatment plots. Needle litter had a significant effect on initial survival of fescue seedlings, but subsequent losses undoubtedly resulted from the interaction of many factors.

Keywords: Pine needles, litter, grass seedlings, ponderosa pine, *Pinus ponderosa.*

REST SERVICE - U.S. DEPARTMENT OF AGRICULTURE - PORTLAND, OREGON

Introduction

Ponderosa pine (*Pinus ponderosa*)[1] often regenerates in dense patches with a sparse understory of shrubs and herbaceous vegetation. Needle litter is only one of many factors influencing understory vegetation in such cases, but its general importance on native species is well documented (Pase 1958 and Moir 1966). The present study was conducted to determine the effect of pine needle fall and accumulation on the emergence and survival of planted grass seedlings.

Methods

The study was conducted near Winthrop, Washington, about 2,000 feet above sea level. Temperature extremes vary from 110° to -30° F., with average July temperature of about 70° F.; and the frost-free growing season extends from May until late September. Approximately 60 percent of the 14.5 inches of average annual precipitation falls between October and February and includes about 70 inches of snow. The soils are well drained, moderately coarse-textured Western Brown Forest Soils, integrated to regosols developed from granitic ablation till.

The study plots were located in dense ponderosa pine poles and saplings (3,000-4,000 stems per acre) with a canopy closure of about 90 percent as measured with a spherical densiometer (Lemmon 1956). The trees were about 55 years old and originated from natural seeding in 1911 after logging and fire. Surviving trees of the original stand, unmerchantable at the time of logging, indicated an above average site IV. Needle litter was from 1 to 4 inches deep, with accumulations of about 10.5 air-dry tons per acre. Needle fall varied significantly between years but averaged about 0.5 air-dry ton annually. The area was not used by livestock, but it received light deer use.

Hard fescue (*Festuca ovina* var. *duriuscula*) was hand seeded on individual 3- by 3-foot treatment plots at a rate of 6 pounds of live seed per acre. The experimental design consisted of the following four litter treatments replicated five times in randomized block design (see fig. 1 for photograph of a typical block layout):

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[1] The source for scientific nomenclature is Hitchcock et al. (1955-69).

1. Remove original litter, plant grass seed, remove new needle fall each spring.

2. Remove original litter, plant grass seed, allow new litter to accumulate.

3. Remove original litter, plant grass seed, replace original litter, and allow new needle litter to accumulate.

4. Broadcast grass seed on undisturbed litter and allow new litter to accumulate.

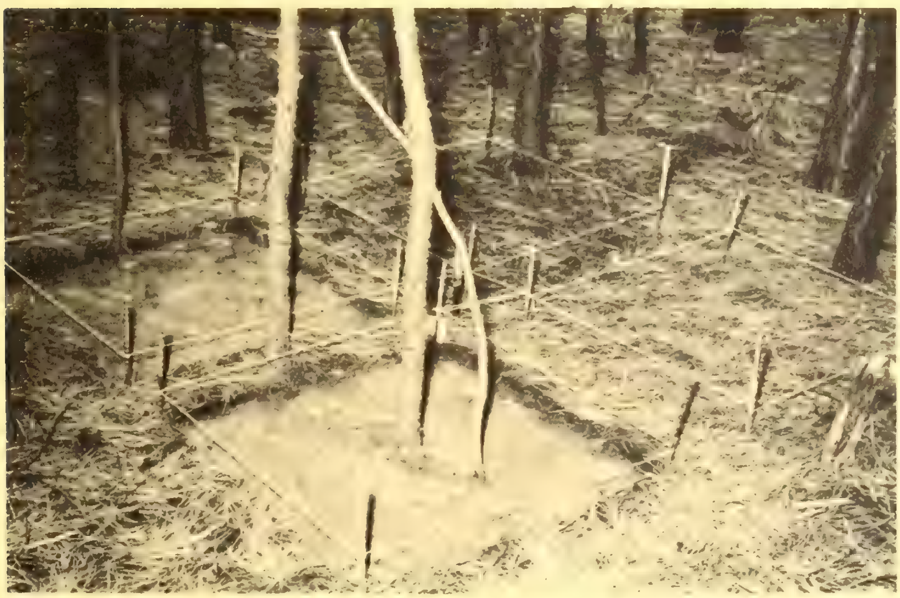

Figure 1.--Typical layout of one block of treatment plots at the start of the study.

The effects of the litter treatments were evaluated by counting all hard fescue plants on each treatment plot at approximately the same stage of growth each spring for a 6-year period. Summer and fall counts were impractical because of the difficulty of distinguishing mature fescue leaves from pine needles. Hard fescue was used because it is somewhat shade tolerant and is probably as adaptable to growth under dense ponderosa pine as most other grass cultivars.

Emergence and survival data were tested with split-plot analysis of variance with treatments considered as whole plots and years as subplots. Separate analyses of variance were also made for individual years.

Results

The overall analysis of variance indicated that there were highly significant effects for litter treatments, years, and the interaction between treatments and years. The analyses of variance by individual years showed that responses of fescue plants to litter treatments were significantly different at the 0.01 probability level during the first 3 years. During the fourth year, treatment differences were significant at the 0.05 level, and by the fifth and sixth years none of the differences between treatments were significant.

Tukey's test (Snedecor 1961, p. 251) was used to compare all treatment means during years when significant differences between survival rates were found. Thus, during the first and second years after planting, all treatment means were significantly different except treatments 1 and 2. During the third and fourth years, only treatments 1 and 4 differed significantly; and by the fifth and sixth years none of the treatment means differed significantly.

Survival curves (fig. 2) emphasized the impact of early losses between fall planting and seedling emergence the following spring on

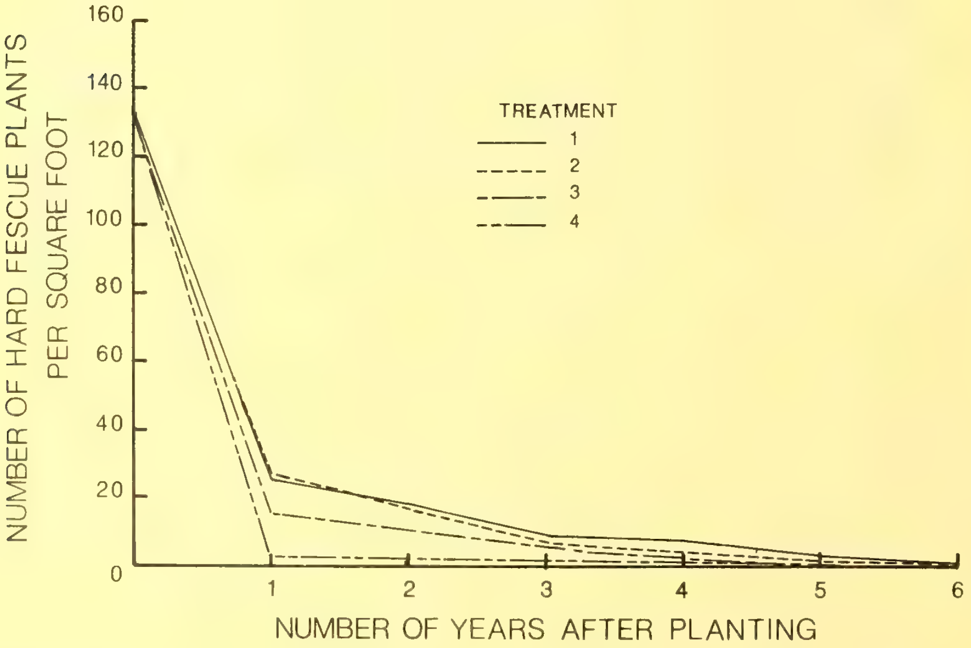

Figure 2.--Number of living hard fescue plants per square foot from seed planting through the 6-year period under four levels of ponderosa pine needle accumulation.

initial inputs of fescue plants into the experimental populations. These early losses ranged from a low of 77 percent of the potential seedling population of 133 plants per square foot in treatment 2, to losses of 80, 88, and 98 percent, respectively, in treatments 1, 3, and 4. The potential seedling populations were determined by finding average seed weight, and thereby the total number of seeds planted per square foot--after corrections for purity and viability--at a seeding rate of 12 pounds per acre.

Discussion

Figure 2 shows that all survival curves for the four experimental hard fescue populations were characterized by heavy mortality in the youngest age groups; this is the most common type of survival curve found in natural populations. There are plausible explanations for the high initial mortality rates of treatments 3 and 4, but possible causes of losses in treatments 1 and 2 are much less obvious. For example, in treatment 4 the thick litter layer might contain considerable water that never penetrates to mineral soil, and these layers could dry out so quickly that germinating seedlings desiccate before their radicles can reach more permanent water supplies in the soil below (Daubenmire 1959). Germinating seedlings in treatment 3 may have had difficulty growing up through the thick litter layer before their food reserves were depleted and they could reach light for photosynthesis.

As previously indicated, no attempt was made to assess the effects of any possible mortality factors except pine needle litter. Undoubtedly, however, seedlings on all treatment plots were also adversely affected by the generally unfavorable growing conditions that characterize the forest floor under dense ponderosa pine canopies. For example, numerous studies have shown that competition between trees and understory plants for moisture, nutrients, etc. is important. Other studies have shown that low light levels on the forest floor contribute to plants with low vigor and reduced growth potential. However, Anderson et al. (1969) found that light levels were apparently above minimum thresholds for species comprising the herb understory in Wisconsin pine forests, and that this layer was more responsive to differences in throughfall precipitation than to differences in light. Also, even though hard fescue plants tolerate mild soil acidity (the pH on the study plots was about 6.0), there can be indirect influences such as soil-borne plant diseases sometimes associated with acid soils. Ponderosa pine needles also contain acid-forming compounds and resins which resist decay and are low in essential nutrients. The ease with which this material dries and the limited involvement of invertebrates in its decay often causes humification characterized by deficient nitrogen. Thus, as Moir (1966) concluded, the trend in herb suppression under dense ponderosa pine canopies is often toward virtual extinction as the effects of shading and soil-nitrogen depletion intensify.

Our results indicate that needle litter had a significant effect on initial survival of fescue seedlings but that subsequent losses undoubtedly resulted from the interaction of many factors. These initial losses are important, however, because they suggest that thick accumulations of needle litter (and its by-products) under dense ponderosa pine canopies may exert a strong selective influence on the eventual composition and cover of understory vegetation.

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ASKA OREGON WASHINGTON
PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
USDA FOREST SERVICE RESEARCH NOTE

PNW-156

PNW-156 July 1971

CHANGES IN GRADE AND VOLUME OF CENTRAL CALIFORNIA WHITE FIR LUMBER DURING DRYING AND SURFACING

UNIVERSITY
NOV 22 1971
TECH. & AGR.

by

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Forest Products Technologist

ABSTRACT

Lumber from 20 white fir trees, totaling over 43,000 board feet, was carefully graded in the rough green, rough dry, and surfaced dry condition. Grade and volume changes occurring after each stage in processing were recorded and analyzed.

Results indicate a considerable loss of grade during drying and surfacing with 43 percent of the green study lumber degrading one or more grades. A total of 55 percent of the rough green study lumber remained on grade or was upgraded after drying and surfacing; 2 percent was lost as trim or cull. Select grades generally degraded more than the Shop and Dimension grades during drying and again during surfacing.

Losses after surfacing accounted for a greater part of the decrease, dropping the overrun from 25.1 percent in the rough green to 24.6 percent in the rough dry to 22.6 percent in the surfaced dry condition.

Keywords: Lumber seasoning, wood quality, lumber, white fir.

ACKNOWLEDGMENT

Appreciation is extended to the American Forest Products Corporation, Martell, California, at whose mill the study was performed and for their assistance during various phases of the study.

INTRODUCTION

The western true firs (*Abies* sp.) are becoming progressively more important as a source of raw material for the wood-using industry. Though they represent only 13 percent of the total commercial softwood sawtimber volume in the West, these species approximate 25 percent of the softwood sawtimber in California. In the central Sierras of California, nearly 50 percent of the sawtimber is made up of red and white fir. In 1967, approximately 2 billion board feet of true fir lumber was produced; of this amount, nearly half was produced in California.

The increasing demand for lumber has placed white fir (*A. concolor* (Gord. & Glend.) Lindl.), once considered an "inferior" species, in a position of being an important source of lumber. This has resulted in an increasing need for up-to-date information on grade recovery for this species. Furthermore, changes in utilization standards, manufacturing, and marketing occurring within the last few years have made it imperative that more recent data on grade and volume change in white fir lumber during processing be available. Information of this type is needed by the Forest Service and other public agencies for timber appraisal and timber quality evaluation, and by lumber industry for evaluating and updating processing procedures.

This report presents data collected during the summer of 1967 in California on the changes in grade and volume after drying and surfacing of white fir lumber. Red fir which is generally included in commercial white fir lumber was not included in this study. These data were part of those collected in a general study designed primarily to investigate some of the more important external-internal relations of wood quality in white fir logs.

The study was performed in cooperation with the University of California Forest Products Laboratory, Richmond, Calif., and the American Forest Products Corporation at Martell, Calif.

PROCEDURE

Twenty white fir trees were selected from a single site in an active logging area in the Eldorado National Forest, Calif. Trees covering as wide a diameter range as could be found in the immediate logging area were selected. Prior to felling, each tree was examined in its natural state; surface characteristics for the first 32 feet were diagramed (Jackson et al. 1963), and other important details of the tree and surrounding area were noted and recorded. Additional diagraming instructions are given in a report by Pong and Jackson (1971). Each tree was numbered, then was felled and bucked into lengths in accordance with the industry practice. Tree and log measurements were recorded (see table 1). Minimum log size taken was 10-foot length, 10-inch d.i.b. (diameter inside bark) at the small end with a net scale of 50 percent of gross scale. Cull logs and logs not meeting minimum size requirements were left in the woods.

Table 1.--*Distribution of size, age, and form class of white fir study trees*

Tree number	D.b.h.	Total height	Age[1]	Form class	
				16 feet	32 feet
	Inches	*Feet*	*Years*		
1	24.3	100	143	72	63
2	23.8	97	95	76	80
3	46.2	142	141	74	69
4	46.4	182	150	79	67
5	18.6	99	145	72	69
6	21.2	110	145	74	70
7	21.5	104	83	78	71
8	17.2	94	79	87	83
9	28.0	137	147	74	70
10	29.8	139	139	80	78
11	37.4	158	144	80	80
12	38.1	160	143	74	67
13	24.9	115	98	68	65
14	20.7	92	94	79	73
15	20.1	88	130	69	56
16	32.4	156	149	75	77
17	46.9	175	169	73	69
18	39.2	165	176	69	63
19	40.7	168	146	74	72
20	37.1	129	109	72	65

[1] At stump height.

In the mill yard, study logs were graded using a system of three grades (Wise and May 1958): Select (grade 1), Shop (grade 2), and Common (grade 3).[1] The Common grade of logs was most numerous. Log lengths varied from 10 to 20 feet (table 2) with greatest concentration in the 16-foot length. Log diameters at the small end varied from 10 to 39 inches (table 3). A total of 112 logs

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[1] *Logs in the Common grade include both high and low Commons (Wise and May 1958).*

Table 2.--*Distribution of study logs by length and log grade*

Log length (feet)	Number of logs by log grades[1]			
	1	2	3[2]	All grades
10	0	0	10	10
12	0	0	9	9
14	0	1	3	4
16	8	11	67	86
18	0	0	2	2
20	0	0	1	1
Total	8	12	92	112

[1] See Wise and May 1958.

[2] Logs in this grade include high and low Commons (Wise and May 1958).

Table 3.--*Distribution of study logs by diameter class and log grade*

Diameter inside bark (inches)	Number of logs by log grades[1]			
	1	2	3[2]	All grades
9.6 - 12.5	0	0	15	15
12.6 - 15.5	0	3	15	18
15.6 - 18.5	0	3	15	18
18.6 - 21.5	0	0	9	9
21.6 - 24.5	1	1	15	17
24.6 - 27.5	1	1	11	13
27.6 - 30.5	3	2	4	9
30.6 - 33.5	2	0	4	6
33.6 - 36.5	0	2	4	6
36.6 - 39.5	1	0	0	1
Total	8	12	92	112

[1] See Wise and May 1958.

[2] Logs in this grade include high and low Commons (Wise and May 1958).

from the 20 study trees were sawn into lumber. Not included in this study were five mill-length study logs which were lost in transit from the field to the mill.

Each log was sawed with the intent of recovering the optimum value through manufacture of usual lumber items. Sawing practices during the study period conformed to general industry practice in the west-side Sierras and were geared to produce Select, Shop, Common, and Dimension lumber. All lumber was sawed to meet Western Wood Products Association (WWPA) specifications.

Boards from each log were identified by color coding and marking with an assigned mill log number and stamped consecutive board numbers. A WWPA grader using purple keel marked all lumber on the green chain by grade. In this grading and all subsequent grading, boards were graded "as is" without regard to an anticipated grade. Trimming of lumber at any stage in the study was restricted to pencil trimming only; actual trimming of the study lumber was not done until after it was surfaced and graded.

It is the practice of the company to segregate the green lumber into three drying sorts (sap, corky, and sinker) (Smith and Dittman 1960) for each of four thicknesses (4/4, 5/4, 6/4, and 7/4). A fourth sort (4- by 4-inch dimension) called "No. 4" or dunnage was cut from the shaky cores. Normally there is no green grading of the white fir lumber by the mill. Study lumber was not tallied in the green condition except for the "No. 4" and all of the 4/4 lumber; these were hand tallied by board number, mill log number, green grade, width, length, and thickness. Since there was to be no further processing of the dunnage and the 4/4 lumber, we assumed the green grade of this lumber would have held true if dried and later if surfaced. The remainder of the lumber was tallied after kiln drying.

After sorting on the green chain, all lumber to be kiln dried was stickered into kiln packages of one drying sort. Since the volume of study material in each sort was not sufficient to fully charge a kiln, packages of green, nonstudy white fir lumber of the same drying sorts were loaded into the kilns for drying with the study lumber.

Modern, single track, internal fan, cross-circulation kilns were used to dry the study lumber. Since there were basically three drying sorts (sap, corky, and sinker), three different kiln charges and three different kiln schedules were used. These time-temperature schedules are listed in table 4. Each schedule gave a 5- to 10-percent redry and an average moisture content of 15 to 16 percent with a maximum moisture content of 19 percent.

After the drying, the same grader that evaluated the lumber in the green condition regraded and marked the lumber on the dry sorting chain.

Table 4.--*Dry kiln schedules for sap, sinker, and corky white fir lumber, American Forest Products Corporation, Martell, California*

Time (hours)	Temperatures		
	Dry bulb	Wet Bulb	Wet bulb depression
	- - - - - - - - - -	*Degrees F.*	- - - - - - - - - -
Sap:			
0-36	160	140	20
37-76	170	140	30
77-100	180	140	40
101-106 conditioning			
Total time: 106 hours			
Sinker:			
0-24	160	140	20
25-60	170	140	30
61-168	180	140	40
169-174 conditioning			
Total time: 174 hours			
Corky:			
0-24	160	140	20
25-54	170	140	30
55-60 conditioning			
Total time: 60 hours			

The rough-dry grade marks were made with red color keel. The grade mark and any pencil trim were made on the same end and side on which the rough-green grade mark and trim appeared. The lumber was then photographed board by board, with color film (Pong et al. 1970). A hand tally of each board was also made. Here the green and dry grades were recorded along with any green and dry pencil trimming, board and log numbers, length, width, and thickness. From the combination of a photo tally and a hand tally, accurate records of the lumber in the rough green and rough dry condition were obtained. Rough dry boards were pulled on the dry sorting chain according to grade, width, and thickness.

Rough dry dimension lumber was planed S4S; Selects, Shops, and Commons were planed S2S. The procedure for tallying at the planer was as follows: boards entering the planer were recorded in turn on data sheets by the consecutive stamped numbers which were originally affixed to the boards on the green chain. As each board left the planer, it was marked by grade, pencil trimmed, and a consecutive number was written on its surface. This number coincided with the number of entries that were made on the data sheets as boards were fed into the planer. Each surfaced board was then photographed with color film (Pong et al. 1970). The same man that graded the rough green and rough dry lumber regraded the surfaced lumber.

DATA PROCESSING

Hand tallied data for rough green and rough dry boards were edited and corrected using the photo tally made on the dry sort chain. The hand tally of consecutive numbers at the infeed of the planer were matched and corrected using the tallies for rough green and rough dry boards. The board data for the surfaced dry lumber were then transferred from the photo tally of surfaced lumber to the tally sheets on which the consecutive stamped numbers, as recorded at the infeed of the planer, had been entered. Keypunch operators transferred the data for each phase of the study from the tally sheets to punch cards. A detailed matching was then made of all boards from rough green to rough dry to surfaced dry for each log. The cards were then analyzed by automatic data processing (ADP) for changes in grade and volume for each stage of processing. Other ADP analyses were made on lumber recovery for different log grades, grades of lumber from different log grades, and overrun percentages. In these analyses, Common grades of lumber, i.e., 2 Common, 3 Common, and 4 Common, were combined with the dimension grades of Standard, Utility, and Economy, respectively (Anonymous 1968).

RESULTS — GRADE AND VOLUME CHANGE

Rough Green to Rough Dry

The volume of lumber that remained on grade during drying ranged from 0 to 88.5 percent of the volumes of green lumber in the several individual grades (table 5). Grade retention was highest in the 1 Shop grade. The Select grades (B Select to Molding) were downgraded consistently more than the Shop grades (3 Clear to 3 Shop) except for 3 Clear, or the Dimension grades (Construction to Economy).

About 12 percent of the volume of green lumber graded out as Selects in the rough dry condition, 13 percent as Shop, and 72 percent as Dimension. Approximately 6 percent of the total volume of green lumber was regraded to a higher grade after drying, 77 percent held true to grade, and 17 percent was downgraded. Dunnage made up 2.5 percent of the lumber volume. As noted previously, this material was not dried or surfaced. Less than 1 percent of the total volume of green lumber was lost through pencil trimming in the rough dry condition.

Because this study did not record reasons for changes in grade, it would be presumptuous to attribute all changes in grade to drying alone. Some of the changes, no doubt, resulted from other causes, i.e., natural defects, mismanufacturing, and evaluation by the grader (Pong and Smith 1962). The fact that the initial conditions for the kiln schedules (see table 4) used in this study are probably better suited for drying dimension lumber and lower grade white fir suggests that they may have been too severe for the upper grades of lumber. Milder schedules (Rasmussen 1961) would have undoubtedly minimized drying defects in these grades.

Rough Dry to Surface Dry

The volume of rough dry lumber that remained on grade during surfacing ranged from 0 to 77.7 percent in the several individual grades (table 6). The Economy grade had the highest percentage. This is to be expected since the characteristics permitted under the grading rules for this lumber grade are much less limiting than for other grades. The next highest percentage remaining on grade was for Molding which registered 59.7 percent. As in the case of drying, the Select grades generally degraded more during surfacing than either the Shop or the Dimension grades. One notable exception was the high downgrading of 1 Shop which, as noted in the previous section, had the highest grade retention after drying.

Of the total volume of rough dry lumber, about 7 percent graded out as Selects after surfacing, 13 percent as Shop, and 75 percent as Dimension. Approximately 9 percent of the rough dry lumber was upgraded after surfacing, 52 percent retained the same grade, and 37 percent was downgraded. Nearly 2 percent of the volume of rough dry lumber was lost during the surfacing as the result of trimming. The first three Select grades (B, C, and D Selects) actually gained instead of losing volume during surfacing. Noting further the very high percentages of downgrading for these grades, one could conclude that trimming alone would not have changed the downgrading pattern of the boards in these grades--some more important downgrading factor or factors, unaffected by trimming, was influencing it.

Rough Green to Surfaced Dry

The volume of rough green lumber that remained on grade after surfacing ranged from 0 to 82.1 percent for the various individual grades (table 7).

The lowest grade, Economy, had the highest grade retention followed by Construction with a 51.3-percent retention. Select grades generally were downgraded considerably more than the Shop and Dimension grades; a high amount of downgrading was recorded for 1 Shop. Most of the downgrading of 1 Shop was recorded during the surfacing of the rough dry material (see table 6); a small amount was recorded after the green lumber was dried (see table 5).

About 7 percent of the volume of rough green lumber graded out as surfaced dry Selects, 13 percent as Shop, and 75 percent as Dimension. More than 8.5 percent of the green lumber was upgraded, 46.8 remained unchanged, and 42.5 was downgraded in the surfaced dry condition. A 2.1-percent loss in volume from rough green to surfaced dry was recorded.

The unchanged volume percentages in table 7 can be compared with those presented in table 5 since both are based on green lumber volume. As expected, the unchanged volume percent for various grades of rough green lumber in the surfaced dry condition (table 7) showed a marked drop when compared with recorded values in the rough dry condition (table 5). Most of this change was recorded as an increase in the volume of downgraded lumber in each of the individual grades. There was also a noticeable increase in loss of volume for each individual grade; how much was caused by surfacing alone cannot be ascertained. It can be assumed, however, that not all of the increase in downgrading for the individual grades is the result of surfacing alone. Cause of this downgrading no doubt was already present in the rough dry lumber before surfacing and went undetected until after surfacing. Thus, surfacing in reality gave the grader a better specimen to examine and to evaluate and eliminated much of the guesswork which goes into grading rough boards.

As previously noted, the upper grades of lumber had less volume remaining on grade than the lower grades of lumber after each step of processing. This is to be expected because of more stringent grading rules for upper grades of lumber. Furthermore, because appraising upper grades is more difficult (Pong and Smith 1962), the potential for errors in evaluating these grades is probably greater than in the lower grades. In the lower grades, some inaccuracies in evaluating grading defects after each step in processing may have little effect on the lumber grade.

A comparison of the figures in tables 6 and 7 for lumber retaining its grade gives some indication of the effectiveness of grading green lumber as opposed to grading dry lumber in segregating the various lumber grades prior to surfacing. Table 7 shows the percentage of lumber in the various grades of green lumber which would have retained the same grade after drying and surfacing. In table 6, the percentages of volume unchanged for the individual grades of rough dry lumber represent the lumber retaining the same grade

Table 5.--Volume of white fir lumber recovere

Grade of rough green lumber	Volume of rough green lumber	Grades of lumber							
		B Select	C Select	D Select	Molding	3 Clear	1 Shop	2 Shop	3 Shop
	Bd. ft.	*Percent*[1]							
B Select	753	50.9	24.3	2.7	17.2	0	0	0	0
C Select	855	1.9	32.0	31.4	14.9	1.9	0	6.2	0
D Select	2,619	.7	6.6	54.1	8.9	.2	2.0	11.6	0
Molding	2,100	0	0	5.6	66.4	0	.9	13.2	.7
3 Clear	29	0	0	36.4	0	0	0	0	0
1 Shop	595	0	0	0	0	0	88.5	11.8	0
2 Shop	4,588	0	.7	.9	1.5	0	.3	80.8	4.1
3 Shop	161	0	0	0	0	0	0	0	82.0
Construction	16,300	0	0	.5	0	0	0	.4	0
Standard	6,108	0	0	.2	0	0	0	1.4	.4
Utility	5,399	0	.2	.1	.1	0	0	.8	0
Economy	2,510	0	0	0	0	0	0	1.0	1.0
Cull	0	--	--	--	--	--	--	--	--
Dunnage	1,072	--	--	--	--	--	--	--	--
Average	43,089	1.0	1.6	4.6	4.5	0	1.4	10.8	.9

[1] Percentages are based on the accumulation and/or differences in board volumes within each of the categories shown and not on the accumulation or differences of individual

Table 6.--Volume of white fir lumber recovered from

Grade of rough dry lumber	Volume of rough dry lumber	Grades of lumber							
		B Select	C Select	D Select	Molding	3 Clear	1 Shop	2 Shop	3 Shop
	Bd. ft.	*Percent*[1]							
B Select	417	36.8	16.5	21.8	14.8	0	2.9	1.4	0
C Select	672	2.5	9.9	31.6	14.4	0	3.6	14.1	7.1
D Select	1,977	0	5.2	15.5	8.6	0	6.2	21.8	8.5
Molding	1,959	0	0	12.5	59.7	0	8.6	12.2	1.1
3 Clear	21	0	0	75.0	0	0	0	0	0
1 Shop	613	0	0	0	0	0	13.2	64.8	9.8
2 Shop	4,633	0	0	.6	2.8	0	2.2	44.7	19.2
3 Shop	382	0	0	0	5.6	0	0	10.0	54.1
Construction	14,818	0	0	0	0	0	0	.6	1.2
Standard	7,842	0	0	.1	0	0	0	.3	.9
Utility	5,873	0	0	0	0	0	0	1.0	1.3
Economy	2,615	0	0	0	0	0	0	.4	2.7
Cull	11	0	0	0	0	0	0	0	0
Dunnage	1,072	--	--	--	--	--	--	--	--
Average	42,905	.4	.6	2.1	3.8	0	1.2	8.1	4.1

[1] Percentages are based on the accumulation and/or differences in board volumes within each of the categories shown and not on the accumulation or differences of individual

various grades of rough green lumber after drying

Grades of lumber (continued)						Unchanged	Down-graded	Upgraded	Volume loss
truction	Standard	Utility	Economy	Cull	Dunnage				
					Percent[1]				
4.3	0	0	0	0	--	50.9	48.5	0	0.7
6.2	3.7	.4	0	0	--	32.0	64.7	1.9	1.4
9.8	3.6	1.9	0	0	--	54.1	38.1	7.3	.5
2.0	4.0	4.4	2.3	0	--	66.4	27.5	5.6	.5
54.5	0	0	0	0	--	0	54.5	36.4	9.1
0	0	0	0	0	--	88.5	11.8	0	+.3
2.6	3.1	6.0	0	0	--	80.8	15.8	3.4	0
0	0	9.9	3.7	0	--	82.0	13.7	0	4.3
82.6	13.7	2.5	0	0	--	82.6	16.2	1.0	.3
10.9	74.0	11.7	.8	0	--	74.0	12.5	12.8	.7
2.9	13.2	74.4	7.5	0	--	74.4	7.5	17.3	.9
.8	1.2	11.8	83.6	.4	--	83.6	.4	15.8	.2
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	100.0	[2] 100.0	--	--	--
34.4	18.2	13.6	6.1	0	2.5	76.7	16.6	6.4	.4

centages. This may result in some minor differences in percentage totals.

[2] Not dried or surfaced.

ous grades of rough dry lumber after surfacing

Grades of lumber (continued)						Unchanged	Down-graded	Upgraded	Volume loss
struction	Standard	Utility	Economy	Cull	Dunnage				
					Percent[1]				
0	2.2	6.1	1.3	0	-	36.8	67.0	0	+3.8
9.7	2.0	6.9	0	0	--	9.9	89.5	2.5	+1.8
13.5	11.1	6.4	4.2	0	--	15.5	80.3	5.2	+1.0
.4	2.9	.3	2.3	0	--	59.7	27.7	12.5	0
0	0	0	25.0	0	--	0	25.0	75.0	0
0	0	0	3.9	0	--	13.2	78.5	0	8.3
5.4	4.8	4.1	3.8	0	--	44.7	37.4	5.6	12.3
0	0	0	21.0	0	--	54.1	21.0	15.6	9.3
57.8	31.0	7.5	1.8	0	--	57.8	40.3	1.8	.2
13.9	50.2	29.8	4.7	0	--	50.2	34.5	15.1	.2
2.3	18.3	45.1	31.5	0	--	45.1	31.5	22.9	.5
0	1.4	14.6	77.7	1.0	--	77.7	1.0	19.1	2.2
0	0	0	75.0	0	--	0	0	75.0	25.0
--	--	--	--	--	100.0	[2] 100.0	--	--	--
24.2	23.7	16.0	11.5	.1	2.5	52.0	37.0	9.3	1.6

rcentages. This may result in some minor differences in percentage totals.

[2] Not dried or surfaced.

Table 7.--Volume of white fir lumber recovered from var

Grade of rough green lumber	Volume of rough green lumber								
		B Select	C Select	D Select	Molding	3 Clear	1 Shop	2 Shop	3
	Bd. ft.	- - - - - - - - - - - - - -	-	- -	*Percent*[1/]	- -	- -	- -	-
B Select	753	22.6	7.8	20.7	23.5	0	8.5	4.6	
C Select	855	0	7.4	26.0	12.0	0	17.6	11.9	
D Select	2,619	0	4.4	13.1	12.6	0	3.5	23.3	
Molding	2,100	0	0	7.4	45.1	0	2.7	14.2	
3 Clear	29	0	0	0	0	0	0	0	
1 Shop	595	0	0	0	1.3	0	7.4	55.8	1
2 Shop	4,588	0	0	.6	1.7	0	2.2	39.0	1
3 Shop	161	0	0	0	4.7	0	0	5.0	4
Construction	16,300	0	0	0	0	0	0	1.1	
Standard	6,108	0	0	0	0	0	0	1.1	
Utility	5,399	0	0	0	0	0	0	.7	
Economy	2,510	0	0	0	0	0	0	.4	
Cull	0	--	--	--	--	--	--	--	
Dunnage	1,072	--	--	--	--	--	--	--	
Average	43,089	.4	.6	2.1	3.8	0	1.2	8.0	4

[1/] Percentages are based on the accumulation and/or differences in board volumes wi in each of the categories shown and not on the accumulation or differences of individual

after surfacing. These results indicate that, in general, grading of rough green lumber is less effective than grading of rough dry lumber in segregating lumber for surfacing. An obvious advantage of grading after drying is the appearance of drying defects which grading of rough green lumber alone cannot fully foresee. The higher figures in table 6 for retention of grade were probably the direct result of this. It should be noted, however, that the two lowest lumber grades, Utility and Economy, did not follow this pattern. In both of these grades, grade retention was less than that recorded in table 7. The advantages of grading of dry lumber over grading of green in segregating lumber for surfacing in these two grades appear to be minimal.

On the average, grading of dry lumber resulted in 52-percent retention of grade after surfacing, with 37 percent downgraded, and 9.3 percent upgraded (table 6). The same figures for grading of green lumber are, respectively, 46.8, 42.5, and 8.6 percent (table 7).

LUMBER GRADE RECOVERY

Table 8 presents the percentages of lumber grade recovery by log grade for study lumber in the rough green, rough dry, and surfaced dry condition.

es of rough green lumber after drying and surfacing

Grades of lumber (continued)						Unchanged	Downgraded	Upgraded	Volume loss
truction	Standard	Utility	Economy	Cull	Dunnage				
Percent[1]									
9.1	1.2	3.4	0.7	0	--	22.6	79.6	0	+2.1
3.7	13.4	3.0	1.9	0	--	7.4	91.9	0	.7
15.0	10.1	7.7	2.2	0	--	13.1	81.3	4.4	1.3
3.3	9.7	2.8	4.5	0	--	45.1	44.8	7.4	2.7
90.9	0	0	0	0	--	0	90.9	0	9.1
4.7	0	0	4.0	0	--	7.4	81.2	1.3	10.2
6.2	7.5	6.5	6.6	0	--	39.0	45.8	4.5	10.6
0	0	9.9	24.8	0	--	46.9	34.8	9.6	8.7
51.3	33.3	10.2	2.5	0	--	51.3	46.0	2.1	.6
14.7	43.9	28.6	9.5	.2	--	43.9	38.2	17.0	.9
3.9	20.7	47.1	25.1	0	--	47.1	25.1	26.3	1.5
0	.2	11.7	82.1	.6	--	82.1	.6	15.5	1.8
--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	100.0	[2]100.0	--	--	--
24.1	23.6	15.9	11.5	.1	2.5	46.8	42.5	8.6	2.1

centages. This may result in some minor differences in percentage totals.

[2] Not dried or surfaced.

Percentage of lumber recovered in the rough green, rough dry, and surfaced dry condition in each lumber grade for all log grades combined is also presented.

As expected, the higher grade logs (grades 1 and 2) produced more lumber in the upper grades (Selects and Shops) than did lower grade logs (grade 3), which produced more Dimension grades of lumber.

A comparison of the lumber recovery between grades 1 and 2 logs indicates that the recovery from these log grades is essentially the same in the rough green and rough dry stages. Notable exceptions are the percentages of recovery for 1 Shop (rough green) and 3 Shop, and the Economy grade. The recovery of the Economy grade was exceptionally high from the grade 2 logs in both the rough green and rough dry as well as in the surfaced dry condition. No doubt this high percentage of recovery is related to the low recovery of dunnage (0.8 percent) in the grade 2 logs; dunnage recovery in grades 1 and 3 logs was, respectively, 3.3 and 2.7 percent.

In the surfaced dry condition, percentages of lumber recovery for grades 1 and 2 logs differed most noticeably in the Select, 3 Shop, and the

Table 8.--Percentages[1] of lumber grade recovery by log grade for lumber in the rough green, rough dry, and surfaced dry condition

Log grade[2]	Grades of lumber													
	B Select	C Select	D Select	Molding	3 Clear	1 Shop	2 Shop	3 Shop	Construction	Standard	Utility	Economy	Cull	Dunnage
Rough green:														
1	4.5	4.8	18.1	11.9	0.3	1.3	9.2	1.6	23.8	7.8	11.0	2.4	0	3.3
2	5.4	3.9	15.2	8.9	.2	.2	13.1	.1	24.7	7.1	10.1	10.3	0	.8
3[3]	.6	1.1	2.2	2.8	0	1.6	10.5	.2	42.8	16.6	13.3	5.6	0	2.7
All	1.7	2.0	6.1	4.9	.1	1.4	10.6	.4	37.8	14.2	12.5	5.8	0	2.5
Rough dry:														
1	2.3	4.4	14.9	11.9	0	.7	12.5	3.4	22.5	12.6	9.4	2.1	0	3.3
2	3.4	5.0	11.9	9.4	0	1.1	13.4	.5	23.9	10.2	10.2	10.2	0	.8
3[3]	.3	.4	1.4	2.3	.1	1.6	10.0	.5	38.6	20.7	15.1	6.1	.1	2.7
All	1.0	1.6	4.6	4.6	(4/)	1.4	10.8	.9	34.5	18.3	13.7	6.1	(4/)	2.5
Surfaced dry:														
1	0.1	.8	6.4	13.4	0	2.2	11.5	8.7	20.7	15.0	9.5	8.4	0	3.3
2	1.9	2.1	4.8	6.8	0	2.6	11.7	4.6	19.6	15.2	14.9	15.0	0	.8
3[3]	.2	.2	.9	1.6	0	.8	7.0	3.3	26.3	27.5	17.8	11.7	.1	2.7
All	.4	.6	2.1	3.9	0	1.2	8.2	4.2	24.6	24.2	16.3	11.7	.1	2.5

[1] Percentages may not total correctly because of rounding.

[2] See Wise and May 1958.

[3] Logs in this grade include high and low Commons (Wise and May 1958).

[4] Less than 0.05 percent.

lower Dimension grades. Recovery of Selects (B, C, D Selects and Molding) was 20.7 percent for grade 1 logs and 15.6 percent for grade 2. In grade 1 logs, more than half of the recovery of Selects was in Molding, and in grade 2 logs, less than half was in Molding. The recovery of 3 Shop from grade 2 logs was about half of that recovered from grade 1 logs. In grade 2 logs, the lower grades of Dimension (Utility and Economy) made up nearly 30 percent of the volume recovered; in grade 1, almost 18 percent.

Recovery of surfaced dry Selects from grade 3 logs was 2.9 percent; Shop grades of lumber totaled 11.1 percent, and Dimension, 83.3. Comparable figures for grade 1 logs are: Selects, 20.7 percent; Shops, 22.4; Dimension, 53.6. For grade 2 logs, these figures are: Selects, 15.6 percent; Shops, 18.9; and Dimension, 64.7. For all logs combined, Selects totaled 7 percent; Shops, 13.6 percent; and Dimension, 76.8 percent of the recovery of surfaced dry lumber.

Log Defect Percent, Lumber Tally, and Overrun

Table 9 summarizes the log scale and percent of defect in study logs for each of the log grades. Tallies of recovery of rough green, rough dry, and surfaced dry lumber are also presented. For grade 1 logs, the percent of defect averaged 4.5 percent; grade 2, 4.7 percent; and grade 3, 5.3 percent. For individual logs, percentages of defect registered much higher (table 10). The average deduction for defect for all logs was 5.1 percent of the gross log scale.

Losses for each grade of log due to processing increased with each step in the processing (see table 9). These losses, however, were not substantially different for any given step in processing among various grades of logs--losses from rough green to rough dry were 0.2 to 0.5 percent and from rough dry to surfaced dry, 1.3 to 1.8 percent. Average for all logs combined was: rough green to rough dry, 0.4 percent; and rough dry to surfaced dry, 1.6 percent.

Losses resulting from processing are also reflected in the change in the overrun (see table 9). For each log grade, a decrease occurred in the overrun with each processing step. Similar results can be seen for the overrun for all logs combined.

Tallies of the rough green, the rough dry, and the surfaced dry lumber showed that overrun values increased with decreasing log grade (table 9). A consistent overrun differential between log grades 1 and 2 of approximately

Table 9.--*Summary of log scale, defect, lumber recovery, losses, and overrun by log grades*

Log grade[1]	Number of logs	Log scale		Defect[2]	Lumber recovery			Losses		Overrun[3]		
		Gross	Net		Rough green	Rough dry	Surfaced dry	Rough green to rough dry	Rough dry to surface dry	Rough green	Rough dry	Surfaced dry
		- *Board feet* -		*Percent*	- - - *Board feet* - - -			- - - - - - - - - - - - *Percent* - - - - - - - - - - - -				
1	8	5,280	5,040	4.5	5,870	5,857	5,752	0.2	1.8	16.5	16.2	14.1
2	12	4,870	4,640	4.7	5,708	5,654	5,580	.5	1.3	23.0	21.9	20.3
3[4]	92	26,140	24,760	5.3	31,511	31,394	30,888	.4	1.6	27.3	26.8	24.7
Total	112	36,290	34,440	5.1	43,089	42,905	42,220	.4	1.6	25.1	24.6	22.6

[1] See Wise and May 1958.

[2] Percent gross log scale.

[3] Percent net log scale.

[4] Logs in this grade include high and low Commons (Wise and May 1958).

Table 10.--*Overrun and losses for rough green, rough dry, and surfaced dry lumber, and log scale defect for various study-log diameter classes*

Diameter class[1] (inches)	Number of logs	Overrun[2]			Defect[3]	Losses	
		Rough green	Rough dry	Surfaced dry		Rough green to rough dry	Rough dry to surfaced dry
					Percent		
10	9	64	66	66	7.7	+1.4	0.2
11	1	66	66	61	0	0	2.7
12	5	42	41	49	0	.5	+5.8
13	7	42	40	40	1.5	1.4	.4
14	5	55	54	51	4.6	1.0	1.9
15	6	34	33	34	1.2	.8	+.6
16	8	35	32	33	3.1	2.2	+.9
17	7	34	35	33	3.9	+.8	1.4
18	3	28	27	28	0	.8	+.5
19	4	51	50	46	2.2	.8	2.2
20	4	26	25	25	2.7	.8	+.1
21	1	26	28	27	0	+1.9	.8
22	7	33	33	33	1.4	.3	0
23	5	27	27	27	4.8	.2	.2
24	5	32	32	31	4.7	.2	1.0
25	4	21	20	18	.6	1.1	.9
26	3	13	12	11	3.8	.9	1.0
27	6	21	21	19	5.5	.1	2.2
28	3	27	26	23	9.8	.5	2.6
29	2	17	17	11	.8	+.3	5.7
30	4	17	17	16	4.9	.3	.3
31	2	13	13	06	16.1	+.5	6.8
32	3	22	21	17	6.3	.3	3.3
33	1	07	07	05	14.1	.1	1.8
34	2	17	17	10	5.0	.1	6.0
35	3	25	24	19	9.9	.3	4.4
36	1	12	09	11	4.3	3.2	+2.3
37	0	--	--	--	--	--	--
38	0	--	--	--	--	--	--
39	1	07	07	04	6.2	.6	2.3
All classes	112	25	25	23	5.1	.4	1.6

[1] Diameter inside bark class.

[2] Percent net log scale.

[3] Percent gross log scale.

6 percent, between grades 2 and 3 of more than 4 percent, and over 10 percent between grades 1 and 3, was recorded in the tallies regardless of the stage of processing.

The higher overrun values recorded for the lower grades of logs (table 9) are, no doubt, due in part to the greater occurrence of smaller diameters in these logs (see table 3) which, because of the Scribner rule, results in a greater overrun. Percent of overrun by 1-inch diameter classes for the study logs is presented in table 10. From this table, it can be seen that overrun for the smaller logs is much higher than for the larger logs.

Based on the individual tallies for study logs, curves of rough green, rough dry, and surfaced dry overrun versus log diameter were calculated by least squares and plotted. These curves are presented in figure 1; each is highly significant at the 1-percent level for 109 degrees of freedom. The curve for rough green overrun and the curve based on the tally of rough dry lumber are similar for the range of log diameters included in this study. The curve for surfaced dry overrun, however, though similar for smaller logs, showed an increasing deviation from the curves for rough green and rough dry lumber with increasing log diameter. This deviation is significant and is related to the loss of volume which occurred during the drying and surfacing of the study lumber; losses from drying averaged 0.4 percent and from surfacing, 1.6 percent (tables 5 and 6). Overrun decreased from 25.1 percent in the rough green condition to 24.6 percent in the rough dry to 22.6 percent in the surfaced dry condition (table 9).

Comparison of the figures for losses in table 10 shows that the losses for the rough green to rough dry stage were much less than those associated with surfacing. Furthermore, a trend was evident that the losses associated with surfacing increased with increasing log diameter. No such trend was evident with drying.

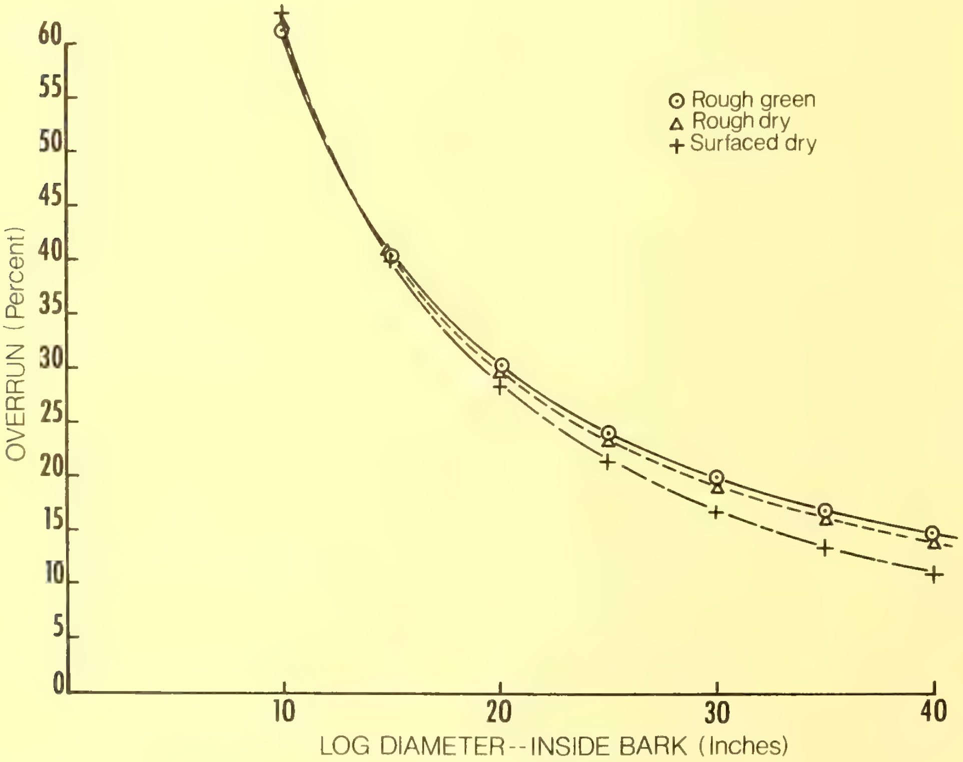

Figure 1.--*Percent overrun vs. log diameter for white fir at different stages of processing.*

CONCLUSIONS

It should be emphasized that the results of this study apply only to the sample tested. To extrapolate these results to white fir in general is dependent on how representative the sample is of white fir. It may be useful, however, to draw from the data certain conclusions regarding grade and volume changes in white fir lumber during processing.

This study indicates a considerable loss of grade during the processing of white fir lumber. Of the 43,000 board feet of green lumber processed in this study, 42.5 percent was downgraded one or more grades during drying and surfacing, 46.8 percent remained on grade, 8.6 percent was upgraded, and 2.1 percent was lost as trim or cull. In general, the Selects were downgraded more than either the Shop or Dimension grades during drying and again during surfacing.

Grading of green lumber was found to be less effective than grading of dry lumber in segregating lumber for surfacing. Grading of dry lumber resulted in approximately 5 percent higher retention of grade and 5 percent less downgrading in the final surfaced volume.

As expected, higher grade logs (grades 1 and 2) produced more upper grades of lumber (Selects and Shops) than the lower grade logs (grade 3) which produced more Dimension grades of lumber.

Losses in lumber tally for each grade of log increased with each step in processing, averaging 0.4 percent during drying and 1.6 percent during surfacing. For any given step in processing, these losses were not substantially different among the various grades of logs.

Overrun decreased with each step in processing, reflecting the processing losses that resulted after drying and surfacing of the lumber. Losses from surfacing accounted for a greater part of the decrease, causing a drop in overrun from approximately 25 percent in the rough green and rough dry conditions to less than 23 percent in the surfaced dry condition.

Increases in overrun with decreasing grades of log were tallied for the rough green, rough dry, and surfaced dry lumber. A preponderance of smaller diameters in the lower grades of logs appears to account for the higher overrun from these logs. A 10-percent overrun differential between extremes in grades of logs exists.

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USDA FOREST SERVICE RESEARCH NOTE

PNW 157 July 1971

EFFECTS OF SEMISTARVATION DURING LATE LARVAL STAGES ON SURVIVAL AND FECUNDITY OF THE HEMLOCK SAWFLY IN THE LABORATORY

CLEMSON
NOV 22 1971
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by

J. S. Hard, *Entomologist*

ABSTRACT

Laboratory feeding tests indicate that hemlock sawfly populations are partially regulated by food quality. Semistarvation of late-instar larvae, due to feeding on current year's foliage rather than on the normal diet of previous year's foliage, caused a 65-percent reduction in survival of females versus 10 percent in males and a 26-percent reduction in fecundity of surviving females. This selective effect on females may account for the sawfly's apparent inability to reach outbreak proportions comparable to those of such lepidopterous defoliators as the black-headed budworm in coastal Alaska.

Keywords: Entomology, larvae, hemlock sawfly, *Neodiprion tsugae*, western hemlock, *Tsuga heterophylla*.

INTRODUCTION

Hemlock sawfly, *Neodiprion tsugae* Midd., outbreaks occur sporadically in southeast Alaska. In the past, sawfly populations frequently occurred with black-headed budworm, *Acleris variana* (Fern.), populations, but were considered of secondary importance. Since the 1965 area-wide collapse of budworm populations in southeast Alaska (Schmiege 1966), sawfly populations alone have caused heavy defoliation of western

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hemlock, *Tsuga heterophylla* (Raf.) Sarg. These sawfly infestations have been confined to localized areas, however, and did not reach the epidemic status common to previous black-headed budworm populations in southeast Alaska.

As with many other conifer-feeding sawflies (MacAloney and Schmiege 1962), the hemlock sawfly normally feeds on previous years' foliage. At high population levels, the "old" foliage is depleted before completion of larval development, and late instar larvae are forced to feed on current year's or "new" foliage. When a hemlock sawfly population is high, a decline frequently follows due to some natural cause such as starvation, disease, parasitization, or a combination of such factors.

This experiment shows direct effects of semistarvation on survival and fecundity of the hemlock sawfly during late larval development. It also suggests that semistarvation was a primary cause of some recent sawfly population declines at scattered locations in southeast Alaska.

METHODS

A feeding experiment using 600 predominantly fourth-instar sawfly larvae was performed under laboratory conditions of 60° F., 75- to 80-percent relative humidity, and 16-hour photoperiod. This approximates dry field conditions in late July and early August. Larvae for the test were collected July 24, 1968, from an apparently healthy field population on hemlock foliage. Each was randomly assigned to a treatment to increase chances of similar sex ratios among treatments since larval sex can be determined only by dissection.

Treatment A consisted of feeding larvae normal hemlock foliage; treatment B, feeding larvae current year's foliage only; and treatment C, placing larvae on bare hemlock twigs. Cut ends of sprigs of foliage and twigs were immersed in water. Each treatment was composed of 10 replicates of 20 larvae per 2x5x7-inch clear plastic cage.

Cage contents were examined on alternate days, and foliage was replaced in treatment A and B cages as needed until all larvae had spun cocoons or died. Unfortunately, sex of dead larvae was not determined because differential mortality of the sexes was not anticipated. Cocoons were placed individually in gelatin capsules until adult sawflies emerged. Females were dissected, and the total number of eggs per female was recorded. Remaining cocoons were dissected and their contents recorded.

Originally, the data were to receive an analysis of variance. However, 14 male adults from treatment A and five male adults from treatment B were used in a sex attractant test and recorded only as to treatment but not by cage number. Therefore, contingency tables were constructed, and chi-square analyses were made to test for significant effects of treatments A and B on overall survival, adult sex ratio, and fecundity. Treatment C was not included in these analyses because complete defoliation of the host has not been observed under natural conditions, and because there were too few female survivors in the treatment to test for differences in fecundity. In addition, bare twigs were not replaced during the test whereas foliage in the other treatments was.

RESULTS

Feeding

Larvae fed mostly on previous years' foliage in treatment A. In treatment B, however, they fed in varying degrees of intensity on "new" foliage, the only food available. Some larvae fed on the bare twigs in treatment C.

Survival

Sawfly survival was lowest under the most stringent feeding conditions of treatment C and the next lowest as a result of treatment B (table 1). Significantly fewer sawflies survived treatment B than treatment A ($\chi^2 = 12.28$, d.f. = 1, $p < 0.005$); therefore, the hypothesis that these two treatments had equal effect on larval survival was rejected. Although some mortality occurred after cocoons were formed, it was not significantly different between treatments ($\chi^2 = 0.57$, d.f. = 1, $p > 0.25$); therefore, the hypothesis that treatments A and B had an equal effect on subsequent mortality was accepted.

Table 1.--*Survival of hemlock sawflies by feeding treatment of late-instar larvae*

Treatment	Test larvae	Dead larvae	Escaped larvae	Cocoons formed	Adult survivors		
					Male	Female	Total
				Number			
(A) Normal foliage	200	37	25	138	70	31	101
(B) Current year's foliage	200	66	28	106	63	11	74
(C) Bare twigs	200	114	20	66	44	2	46

A more striking result was the differential effect of feeding treatment on the sexes (table 1, fig. 1). As intensity of starvation increased, significantly fewer females survived ($\chi^2 = 5.93$, d.f. = 1, $p < 0.025$); therefore, the hypothesis that treatments A and B had an equal effect on male and female larvae was rejected. Feeding on bare twigs affected both male and female survival, and most larval mortality occurred within the first week of the test (fig. 2). Feeding only on "new" foliage had little effect on male survival but affected late-developing larvae (fig. 2) which were mostly females (fig. 3). Since male larvae have one less instar than females, they completed development sooner (Hard and Schmiege 1968) and spun cocoons earlier (fig. 3). To illustrate, in each treatment over 75 percent of male survivors emerged from cocoons formed between July 26 and August 2. In each of treatments A and B, more than 80 percent of female survivors emerged from cocoons formed between August 2 and 19. Therefore, males were less subject to effects of semistarvation.

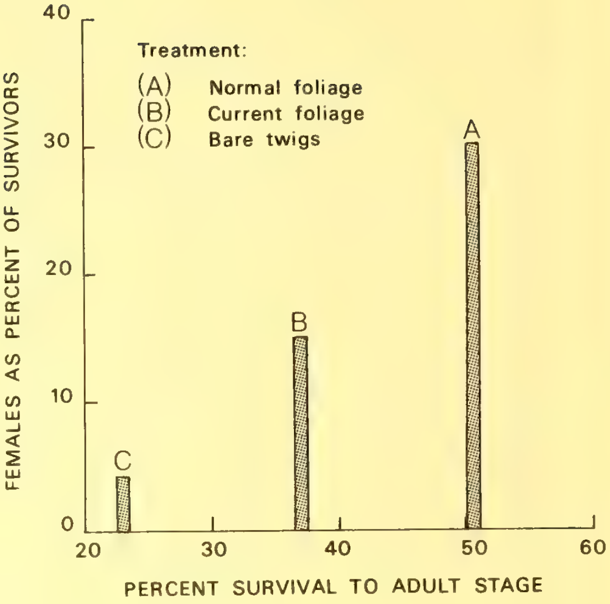

Figure 1.--Relationship between survival of females and survival of both sexes.

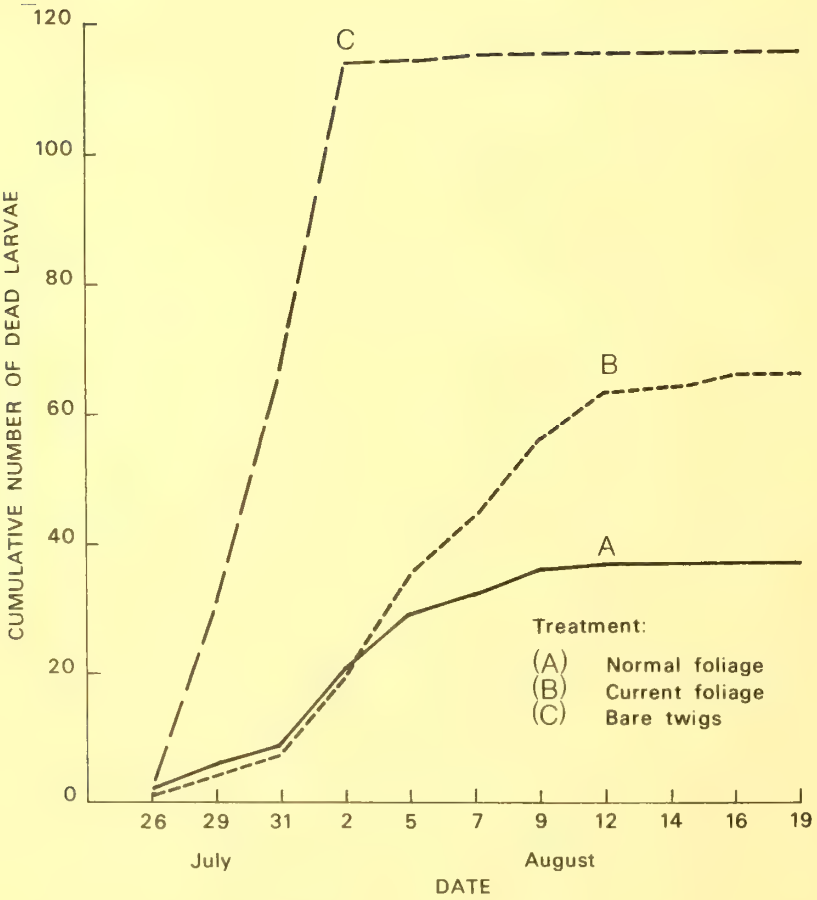

Figure 2.--Cumulative larval mortality by feeding treatment and date.

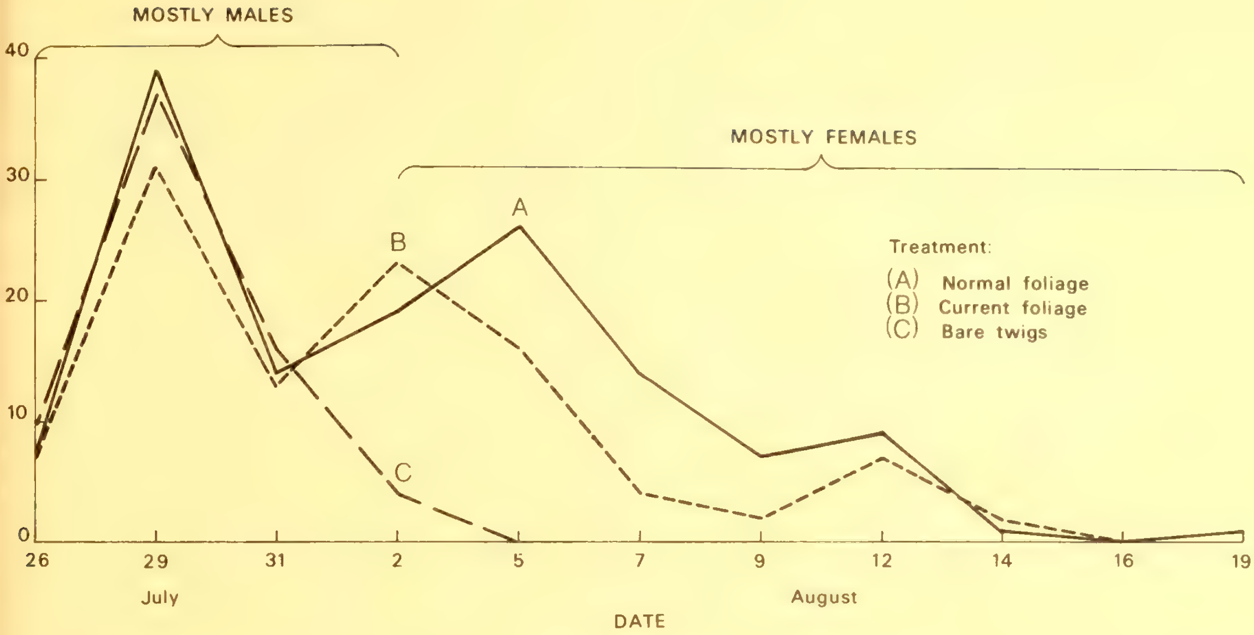

Figure 3.--Cocoon formation by feeding treatment and date.

Crowding stress may have had some effect on larval survival but was apparently not as critical as food quality because the sawfly is a gregarious feeder, although less so in the late instars, and because equal numbers of larvae were placed in the rearing cages.

Fecundity

Of the 44 females that survived the experiment, nine contained dark, free-floating abdominal cysts. These nine (plus two females that escaped) were not included in the egg counts because cysted females are suspected to have a lower than normal fecundity (Sullivan and Wallace 1968). For example, 36 "normal" females from a subsample of 50 additional females contained a mean of 46.19 S.E. ± 2.20 eggs. For the remaining 14 females containing cysts, the mean was 27.79 S.E. ± 3.10 eggs.

The 23 uncysted female survivors of treatment A produced a mean of 50.83 S.E. ± 3.21 eggs, and the 10 uncysted female survivors from treatments B and C produced a mean of 37.30 S.E. ± 2.48 eggs (table 2). The hypothesis that female survivors of treatments A and B had equal fecundities was rejected ($\chi^2 = 21.7$, d.f. = 1, $p < 0.005$). These fecundities are lower than those of healthy field populations (Hard and Schmiege 1968), but relative differences due to like feeding conditions in the field are probably similar. Therefore, it appears that semistarvation of females during the last larval instar can cause a significant reduction in egg production. This is to be expected, since insects feed most heavily during the final instar when most egg substrate is produced (Harcourt and Leroux 1967).

Table 2.--*Effects of diet of late-instar larvae on fecundity of the hemlock sawfly*

Treatment	Females	Eggs produced per female	Range of eggs per female
	- - - - - - - - - - - *Number*	- - - - - - - - - - -	
(A) Normal foliage	23	50.83 S.E. ± 3.21	17-77
(B) Current year's foliage	8	37.63	26-50
		37.30 S.E. ± 2.48	
(C) Bare twigs	2	36.00	29-43

DISCUSSION

Since the summer of 1966, heavy sawfly populations have been observed at Crab Bay and Todd on Chichagof Island, Jamestown Bay near Sitka, and Irish Creek on Kupreanof Island (fig. 4). In all cases trees were heavily defoliated including current year's foliage.

Although the populations collapsed shortly after discovery, exact causes for the declines were not known. Disease and parasitization were proposed as primary causes, but only limited evidence supported these theories. This study suggests that semistarvation of larvae due to depletion of their natural diet of "old" foliage and forced feeding on "new" foliage, a nutritionally inferior substitute, was the primary cause of population decline.

Larval mortality, due directly to starvation in some areas, could have been increased by death of weakened larvae that succumbed to latent disease. Larval mortality would have little adverse effect on sawfly parasites, since all major hemlock sawfly parasite species in southeast Alaska attack after the sawfly larvae have spun cocoons (Torgersen 1969).

Instead, percent parasitization would probably be magnified because of fewer hosts. This situation could have led to a false assumption that disease, parasitization, or both were primary causes of population collapse, whereas semistarvation of larvae may have predisposed the remaining population to high parasitization and disease. Heron (1955) reported effects of starvation on late-instar larch sawfly larvae in Canada. He did not show differential mortality of the sexes, because males are rare in that species, but did show its effect on larval survival and adult fecundity. Similarly, food shortage in late developmental stages of *Tortrix viridana* Linnaeus in Europe causes desertion of the host, more male than female survivors, and reduced fecundity (Schütte 1957).

Reconstruction of events during a hemlock sawfly population collapse at Taku Harbor revealed the following pattern. Despite heavy defoliation in 1964, noticeably fewer cocoons

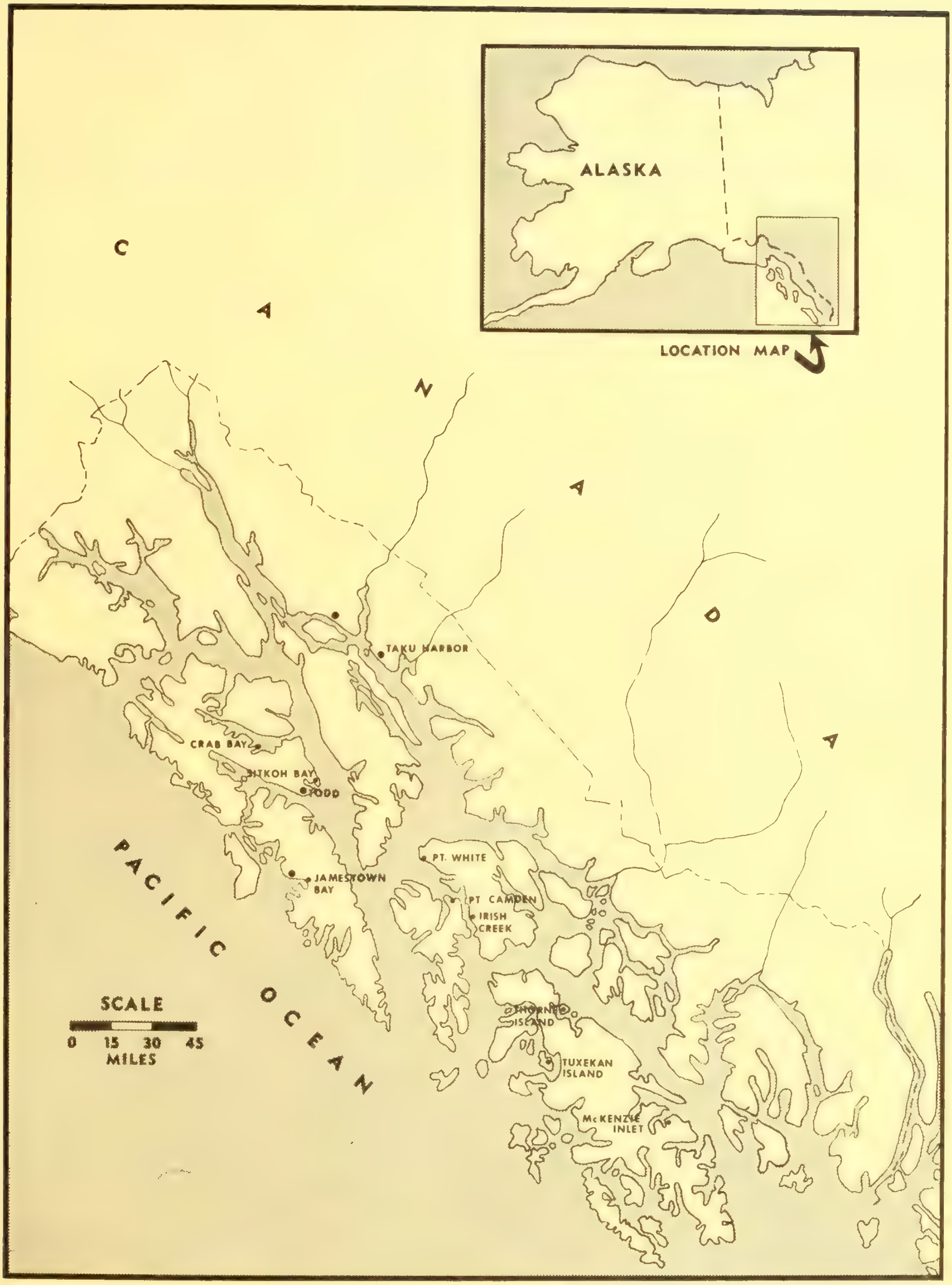

Figure 4.--Southeast Alaska.

were formed than in 1963. Thirty-nine sawflies emerged from a 1964 field sample of 165 cocoons, but only 11 were females. In addition, these females produced a mean of 49.4 S.E. ± 4.0 eggs, whereas 81 females collected in 1963 produced a mean of 72.3 S.E. ± 1.9 eggs.

Semistarvation apparently causes a large reduction in numbers of emerging hemlock sawflies, especially females, and lowered fecundity. This leads to the conclusion that food is an important factor in natural regulation of hemlock sawfly populations and may be primarily responsible for relatively low sawfly population levels in southeast Alaska as compared with budworm population levels. Such a regulatory mechanism would cause a reduction in percentage of females surviving the larval stage, a reduction in fecundity of survivors, and enhancement of subsequent mortality factors such as parasites and disease that attack late in the development of this species.

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USDA FOREST SERVICE RESEARCH NOTE

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UTILIZATION ESTIMATES FOR WESTERN SOFTWOODS--TREES, LOGS, AND RESIDUE

NOV 22 1971

by

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ABSTRACT

How much of the wood fiber volume in trees is used? Estimates of current utilization efficiency in the western softwood industry are provided. They are based on summaries of information obtained in recent studies. Estimates of the volume of wood removed as logs relative to the total volume in the standing tree are presented. The portion of the volume of logs manufactured into lumber or plywood and their associated residues is shown. Utilization of the residues generated during the manufacture of primary products is considered.

Keywords: Log utilization, residue volume, lumber, plywood, recovery ratios, western softwoods.

When trees are harvested, a portion of the available volume of wood fiber is not utilized. Some is left in the woods as logging residue. When logs are manufactured into lumber and plywood, residue in the form of slabs, edgings, trim ends, shavings, and sawdust is produced. Some of this volume of residue is unused.

How much of the wood fiber volume in trees is used? This report provides some answers for western softwoods. Averages developed from summaries of information gathered from various sources are presented. They reflect current utilization efficiency in the western softwood industry. Values in this report are averages. Utilization levels depend upon a number of factors and vary considerably for locations and situations.

Tree Utilization

The portion of a standing tree that is converted to a load of logs destined for a sawmill, plywood plant, or pulpmill depends to a considerable extent on the units of measurement used and the limits they define. Forest Survey of the Forest Service reports nationwide forest statistics based on standard measurement rules for measuring trees. The common units of measurement used are cubic feet and board feet. In Forest Survey, the total fiber content of the bole of a tree is estimated in cubic feet and includes all the wood content of the tree from a stump height of 1 foot above ground to a top diameter of 4 inches. The potential output of product from a tree is estimated in board feet, using the International 1/4-inch log rule, and includes that part from a stump height of 1 foot above the ground to a top diameter limit of 7 inches. These two estimates of volume provide a standard by which use of the tree can be measured.

Trees in this report are only those classed as sound (at least 25 percent of the tree volume is sound wood), a not very restrictive qualification since 93 percent of all tree volume in Washington, Oregon, and California is in sound trees.[1] Volume of cull wood is excluded from this study, even though standards are changing and some types of cull wood are being used.

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[1] *Forest Service, U.S. Department of Agriculture. Timber trends in the United States. Forest Resour. Rep. 17, 235 p., illus., 1965, table 8, p. 150.*

The volume of wood removed as logs by current practices relative to the total volume in the standing tree is shown in the following tabulation (the difference between the figure shown and 100 percent is logging residue):

	Log harvest as a percent of tree volume[1]	
	To a 4-inch top (Cubic feet)	To a 7-inch top (Board feet)
Western Oregon	85.4	92.7
Western Washington	86.8	93.4
Eastern Oregon	94.0	97.0
Eastern Washington	93.5	96.8
California	89.4	94.8
Idaho	89.1	93.9
Montana	86.0	93.1
Arizona	89.1	95.1
New Mexico	89.1	94.2
Wyoming	92.9	98.3
Colorado	89.7	95.8
Utah	93.2	97.5
South Dakota	95.5	99.2

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[1] *Values for cubic-foot volume for the Pacific Coast States are based on field studies by the Pacific Northwest Forest and Range Experiment Station in 1970, except for eastern Oregon and eastern Washington where they are from a 1958 study. Board-foot values for western Oregon, western Washington, and California were estimated based on relationships between board- and cubic-foot values in the other areas.*

Values for other areas are based on the following studies:

Theodore S. Setzer, Alvin K. Wilson, and Grover A. Choate. Logging residues on saw log operations, Arizona and New Mexico. Ogden, Utah, Intermountain Forest & Range Exp. Sta. USDA Forest Serv. Res. Pap. INT-78, 11 p., 1970.

Alvin K. Wilson, Robert E. Green, and Grover A. Choate. Logging residues on saw log operations, Idaho and Montana. Ogden, Utah, Intermountain Forest & Range Exp. Sta. USDA Forest Serv. Res. Pap. INT-77, 12 p., 1970.

Data for Wyoming, Colorado, Utah, and South Dakota are preliminary and are being prepared for publication by the Intermountain Forest and Range Experiment Station.

The volume of wood remaining as logging residue is only one component of the total volume of residues one sees on the ground after logging. Included in the total volumes of residue on the ground are cull materials from both sound and cull trees, accumulations of logs from previously dead trees, limbs, and material left from previous logging.

Log Utilization

Only a portion of the log volume that reaches mills is utilized in the primary product. When lumber is manufactured from logs, residue in the form of slabs, edgings, trim, and sawdust is produced. Planer shavings and trim are produced when lumber is surfaced. In the process of manufacturing plywood, residues such as cores, veneer clippings, and sander dust are produced.

During the past 10 years, the Grade and Quality of Western Timber Project of the Pacific Northwest Forest and Range Experiment Station has conducted a number of recovery studies in which the input log volume and the resulting primary product volume have been accurately measured. Table 1 summarizes by species the average board-foot volume of logs required for the production of 1,000 board feet of surfaced lumber. It also shows the portion of the total cubic-foot volume of logs that was manufactured into lumber or remained as residue. The relative amounts of both lumber and residue vary depending on such factors as size of log, amount and nature of defects, kerf thickness, and the lumber items being produced.

Average volumes of residues produced in lumber manufacture were obtained by Oregon State University from a study of representative Oregon mills.[2] They found that the average volumes of residues produced in the manufacture of 1,000 board feet of lumber were:

Wood use	Volume	
	Cubic feet	Percent
Lumber	65	44.5
Residues:		
Slabs, edgings, sawmill trim	40	27.4
Planer trim	3	2.0
Sawdust	22	15.1
Planer shavings	16	11.0
Total residue	81	55.5
Whole log	146	100.0

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[2] *Unpublished data furnished by Oregon State University, Corvallis.*

Table 1.--*Average log volume required for production of 1,000 board feet of surfaced lumber and associated residues*

Species	Log volume		Lumber recovery ratio	Utilization				Basis
				Lumber		Residue		
	Net log scale[1]	Cubic		Volume	Proportion of log	Volume	Proportion of log	
	Board feet	*Cubic feet*	*Percent*	*Cubic feet*	*Percent*	*Cubic feet*	*Percent*	*Number of logs*
West-side Douglas-fir[2]	836.6	136.7	120	65.5	48	71.2	52	6,326
Western hemlock	826.4	160.1	121	61.7	39	98.4	61	2,301
White fir	829.9	138.2	120	62.4	45	75.8	55	916
East-side Douglas-fir	771.2	150.1	130	63.2	42	86.9	58	4,971
Western larch	785.7	150.2	127	66.1	44	84.1	56	2,810
Engelmann spruce	751.4	145.4	133	66.9	46	78.5	54	1,493
Western white pine	789.4	154.7	127	62.8	41	91.9	59	1,431

[1] Volumes are based on the Scribner Decimal C log rule, National Forest Log Scaling Handbook, USDA Forest Service, January 1969, 193 p. Logs over 20 feet long were segment scaled. Bureau scaling rules are commonly used for west-side Douglas-fir. When the input log volume is determined under these rules, the net log scale requirement is 714.3 board feet instead of 836.6 board feet. The lumber recovery ratio is 140 percent.

[2] West-side Douglas-fir refers to Douglas-fir that grows west of the crest of the Cascade Mountains in Washington, Oregon, and in all of California.

In Alaska, logs are sawn to produce cants for export. The average volume of logs required to produce 1,000 board feet of rough green cants and its utilization are shown in table 2.

The average board-foot volume of logs required for producing the equivalent of 1,000 square feet of 3/8-inch dry veneer or sanded plywood are summarized by species in table 3. The portions of the total cubic-foot volume of logs that were manufactured into dry veneer, plywood, or remained as residue are shown. The volumes for plywood shown in table 3 were developed by adjusting the volume of dry veneer with dry trim, layup, and sander dust loss factors.[3]

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[3] *Douglas L. Hunt and Richard O. Woodfin, Jr. Estimate of dry veneer volume losses in Douglas-fir plywood manufacture. Portland, Oreg., Pac. Northwest Forest & Range Exp. Sta. USDA Forest Serv. Res. Note PNW-134, 10 p., illus., 1970.*

Table 2.--*Average log volume required for production of 1,000 board feet of rough green export cants and associated residues, Alaska*

Species	Log volume		Lumber recovery ratio	Utilization				Basis
				Lumber		Residue		
	Net log scale[1]	Cubic		Volume	Proportion of log	Volume	Proportion of log	
	Board feet	*Cubic feet*	*Percent*	*Cubic feet*	*Percent*	*Cubic feet*	*Percent*	*Number of logs*
Sitka spruce	770.0	158.0	130	88.9	56	69.1	44	1,009
Western hemlock	770.3	188.0	130	83.7	45	104.3	55	1,261

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[1] Volumes are based on Puget Sound Log Scaling and Grading Bureau Scribner Decimal C scaling rules.

Table 3.--*Average log volume required for producing the equivalent of 1,000 square feet of 3/8-inch dry veneer or plywood and associated residues*

Species	Log volume		Veneer-plywood recovery ratios	Utilization				Basis
				[illegible]		Residue		
	Net log scale[1]	Cubic		Volume	Proportion of log	Volume	Proportion of log	
	Board feet	*Cubic feet*	*Percent*	*Cubic feet*	*Percent*	*Cubic feet*	*Percent*	*Number of logs*
Dry veneer:								
West-side Douglas-fir	374.0	59.6	267	30.9	52	28.7	48	1,670
Western hemlock	396.6	74.8	252	32.2	43	42.6	57	412
White fir	354.4	57.8	282	31.3	54	26.5	46	167
Sanded plywood:								
West-side Douglas-fir	464.1	74.0	215	31.3	42	42.7	58	1,670
Western hemlock	492.0	92.8	203	31.3	34	61.5	66	412
White fir	439.7	71.7	227	31.3	44	40.4	56	167

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[1] Volumes are based on the Scribner Decimal C log rules, National Forest Service Log Scaling Handbook, USDA Forest Service, January 1969, 193 p.

Recovery ratios for plywood for representative Oregon mills were obtained by Oregon State University. The average quantities of residues developed in producing the equivalent of 1,000 square feet of 3/8-inch plywood were:

Wood use	Volume of residue	
	Cubic feet	Percent of log
Plywood	34.3	50.4
Residues:		
Log trim	3.4	5.0
Cores	3.7	5.4
Veneer clippings, roundup, and spur trim	18.5	27.2
Sander dust	1.6	2.4
Dry trim and layup loss	6.5	9.6
Total residue	33.7	49.6
Whole log	68.0	100.0

Mill Residue Utilization

Wood residue generated from the manufacture of primary products--lumber, plywood, shingles, and other miscellaneous products--have many attractive features favoring their use. Because of their generally small size--shavings, sawdust, and chips--they are easy to concentrate and to transport by truck, rail or pipeline, and are adaptable to a large number of products and uses. These include use of fiber for pulping; various types of boards such as insulation, particle, and hardboard; fuel for heat and power generation; and agricultural bedding and soil amendments. A 1968 survey[4] of the primary forest industries of the Pacific coast indicates that use of residues is extensive and only a small part of the residues generated (18.7 percent) remains unused (table 4).

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[4] *John A. Bergvall and Donald R. Gedney. Washington mill survey, wood consumption and mill characteristics 1968. Wash. State Dep. Natur. Resour. and Pac. Northwest Forest & Range Exp. Sta., 119 p., illus., 1970.*

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B. R. Barrette, D. R. Gedney, and D. D. Oswald. California timber industries, 1968, mill characteristics and wood supply. Div. Forest., State Calif., 117 p., illus., n.d.

Table 4.--*Production and disposition of wood residue*

(In tons)

State	Total residue	Residue used for				
		Pulp	Board	Fuel	Miscellaneous	Unused
Washington	4,794,471	2,321,626	41,327	1,510,896	236,987	683,635
Oregon	12,234,730	6,362,306	1,168,268	2,452,016	644,652	1,607,488
California	5,868,385	1,817,594	476,925	1,352,565	220,230	2,001,071
Total	22,897,586	10,501,526	1,686,520	5,315,477	1,101,869	4,292,194

Summary

Of the tree harvested, 85-95 percent of the total cubic-foot content of the tree reaches a processing plant.

Of the log processed, 44-50 percent of the total cubic-foot content of the log is used for primary products.

Of the mill residues generated, 81 percent of the total residue is used.

Of the total tree volume, 76-86 percent of the total cubic-foot content of the tree is used.

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USDA FOREST SERVICE RESEARCH NOTE

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DETOXICATION OF AUTOCLAVED SOIL BY A MYCORRHIZAL FUNGUS

by

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ABSTRACT

Douglas-fir seedlings grown in autoclaved soil were stunted and their roots severely aborted. However, when the same autoclaved soil was inoculated with Corticium bicolor, *an ectomycorrhizal fungus, seedlings grew normally. Apparently the fungus deactivated toxin(s) formed during autoclaving of the soil. It is suggested that in nature the mycorrhizal fungus may aid tree growth by protecting absorbing roots from soil phytotoxins.*

KEYWORDS: Soil science, roots, seedlings, soil fungi, *Corticium bicolor*, Douglas-fir, *Pseudotsuga menziesii*.

Autoclaving some soils may destroy fungitoxins (Dobbs and Hinson 1953, Lingappa and Lockwood 1961), believed produced by various microorganisms, while autoclaving other soils has been shown to induce formation of substances toxic to bacteria (Peterson 1962). Most soils, however, display phytotoxicity following autoclaving, the degree of toxicity varying with the soil and with the plant (Johnson 1919).

Rovira and Bowen (1966) found that subterranean clover (*Trifolium subterraneum* L.) planted in autoclaved soil suffered stunting and deformation of its root system. Tomato (*Lycopersicon esculentum* Mill.) was also severely stunted. But, when various fungi and bacteria were introduced into the autoclaved soil, normal plant growth resulted. Five of 13 species of fungi tested detoxicated the soil; these included species of *Aspergillus*, *Humicola*, *Mortierella*, *Penicillium*, and *Pythium*. Reported here is the detoxication of an autoclaved soil by a basidiomycetous ectomycorrhizal fungus.

Loam soil from a western Oregon forest tree nursery was screened, thoroughly mixed, and dispensed into twenty 500-milliliter flasks, 250 milliliters per flask. Distilled water was added to each to adjust the soil to approximately field capacity, and the flasks were then autoclaved for 1 hour at 15 pounds of pressure (121° C.). Following sterilization, they were set aside for 1 week before further treatment.

Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) seed were surface sterilized with 30 percent hydrogen peroxide and germinated on potato-dextrose agar medium. When radicles were 2 to 3 centimeters long, one seed was planted in each flask. At the time of planting, 10 flasks received 5 milliliters of a nutrient solution suspension of mycelium of *Corticium bicolor* Peck., an ectomycorrhizal fungus of Douglas-fir and other tree species. Five milliliters of nutrient solution only were added to each of the remaining 10 flasks. All flasks were then placed in a growth chamber.

Results after 4 months are illustrated in figure 1, *A* and *B*. Seedlings grown in autoclaved soil lacking the fungus (fig. 1, *A*) were badly stunted and chlorotic with short and weakly developed needles. Terminal needles of some seedlings were almost white and the tops of two seedlings were dead. Root systems were severely aborted and consisted of only a taproot or, at most, a taproot and one to three stubby lateral roots. Short roots and root hairs were absent. Most root tips were dark brown and blunt and some were covered with black, clinkerlike tissue. These symptoms were unlike any produced by common adverse soil conditions, such as lack of nutrients, and can only be ascribed to toxins formed during autoclaving of the soil.

In contrast, seedlings grown in autoclaved soil inoculated with *Corticium bicolor* (fig. 1, *B*) were large and vigorous, with long, green needles. Their root systems were well developed with many lateral branches. Tips of lateral roots were vigorously white and tapered. The upper third of the root system bore well-formed mycorrhizae to which dense wefts of mycelium were attached.

Lack of toxin damage to any part of the root system, including nonmycorrhizal lateral roots, in the inoculated soil indicates that *Corticium bicolor* detoxicated the soil mass. And, we may speculate that the fungal mantle and closely attached mycelium of the mycorrhiza

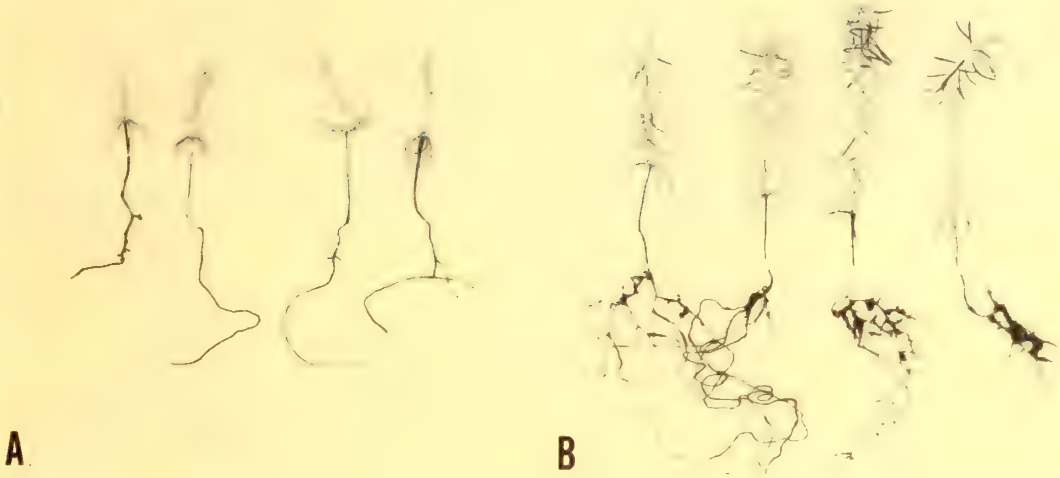

Figure 1.--*Douglas-fir seedlings grown for 4 months in autoclaved soil:* A, *Soil uninoculated;* B, *soil inoculated with* Corticium bicolor; *seedlings are mycorrhizal.*

served as filters blocking entrance of toxic substance(s) into the root. At least, these tissues, together with that part of the fungus permeating the soil, served to deactivate the toxin(s).

Although based on quite unnatural growth conditions, these results may have significance in better understanding the function of the ectomycorrhiza and associated fungal symbiont in growth and survival of the tree in nature. Until recently, the mycorrhiza was thought to benefit the tree wholly by improving the availability and absorption of nutrients. However, a second function of the mycorrhiza is now recognized, that of protecting delicate absorbing root tissue from soil pathogen attack, as outlined by Zak (1964) and clearly demonstrated by experiments of Marx and Davey (1969a, 1969b). The study here reported suggests yet a third function: protection of absorbing roots from soil phytotoxins which, as DeBell (1970) has suggested, may be of importance to tree growth in the forest.

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SKA OREGON WASHINGTON
PACIFIC NORTH WEST FOREST AND RANGE EXPERIMENT STATION

USDA FOREST SERVICE RESEARCH NOTE

PNW-160 August 1971

OCCURRENCE AND GROWTH OF FOUR NORTHWESTERN TREE SPECIES OVER SHALLOW WATER TABLES

by

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and

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ABSTRACT

The occurrence and radial growth of native red alder, western redcedar, Sitka spruce, and western hemlock trees were related to water-table depths from estimates made in skunk-cabbage swamps and stream bottoms on the Olympic Peninsula, Washington. All four species tolerated winter water tables more than 15 centimeters below the soil surface. Red alder and western redcedar also grew well where stagnant water was less than 15 centimeters deep, as did alder and Sitka spruce where the water was flowing. Western hemlock seemed intolerant of water tables less than 15 centimeters deep.

Keywords: Water-table, forest management, western hemlock, red alder, western redcedar, Sitka spruce, Douglas-fir.

INTRODUCTION

Shallow water tables underlie only a small fraction of the Pacific Northwest, but their importance is greater than indicated by the area involved. As recreational use of northwestern lakes and rivers increases, the lowland forests along their edges become increasingly valuable. Many of these forests grow over shallow water tables. As dams are built throughout the region, the resulting reservoirs create more shallow water-table areas. Unfortunately, not all of these newly created lowlands remain forested--upland trees often die when a reservoir creates a new shallow water table. The resulting snag patches are ugly, unproductive, and often avoidable. Several northwestern tree species tolerate shallow water tables. If these tolerant species are properly matched with water-table conditions, attractive and productive forests often can be reestablished.

Quantitative information relating the occurrence and growth of northwestern tree species to water-table depths is scarce. An earlier study of seedling growth over artificial water tables showed that lodgepole pine (*Pinus contorta* Dougl.), western redcedar, (*Thuja plicata* Donn), red alder (*Alnus rubra* Bong.), and Sitka spruce (*Picea sitchensis* (Bong.) Carr.) seedlings grew moderately well over shallow water tables, but Douglas-fir barely survived.[1/] However, the growth and survival characteristics shown by seedlings may not be maintained throughout the life of a tree, and artificial water tables may be different from water tables in the field. In the present study, we measured larger trees in the field to compare the occurrence and growth of red alder, western redcedar, Sitka spruce, and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.).

METHODS

In another study,[2/] depths of winter water tables were found to be correlated with the density and petiole length of yellow skunk-cabbage and the presence or absence of slough sedge (*Carex obnupta* Bail.). These plants were used in the present study to estimate water-table depth. Fifty-six water-table

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[1/] Don Minore. Seedling growth of eight northwestern tree species over three water tables. Portland, Oregon, Pacific Northwest Forest & Range Exp. Sta. USDA Forest Serv. Res. Note PNW-115, 8 p., illus., 1970.

[2/] Don Minore. Yellow skunk-cabbage (*Lysichitum americanum* Hult & St. John)--an indicator of water-table depth. Ecology 50: 737-739, 1969.

plots were established on the Olympic Peninsula, Washington.[3] The plots were located wherever undisturbed native trees and skunk-cabbage were found growing together--without regard to forest type, stand size, or canopy density. Each plot consisted of a 6- to 15-meter line intercept[4] along the contour where there were no hummocks, root wads, or other minor topographic irregularities. (Intercepts shorter than 15 meters were used to estimate water-table depths where topographic irregularities prevented use of a 15-meter line.) Petiole lengths of yellow skunk-cabbage plants encountered on this intercept were measured, and the presence or absence of slough sedge was noted.

Presence of slough sedge indicated an above-surface water table in the winter. Where slough sedge was absent, water-table depths were estimated by measuring the petiole length of the longest leaf on each mature skunk-cabbage plant encountered along the line intercept. These petiole lengths were then used to calculate winter water-table depth estimates for each of the 56 plot locations.[5]

At each location, tree species present at the same elevation as the water-table plot were recorded regardless of tree size. Radial growth for the last 10 years was then measured on a breast-high increment core obtained from a single tree of each species. All growth measurements were obtained from nearby dominant or codominant trees within 5 meters of the water-table plot, at the same elevation. Whenever possible, trees of similar diameter were bored for each species present at a given location. Where the only trees present were overmature (decadent, with flat-topped or partially dead crowns) or too small for increment boring, radial growth was not measured.

General observations of species present on adjacent high ground, movement of ground water, and comparative vigor of species were recorded wherever applicable.

RESULTS

Estimated winter water tables at half of the 56 locations were more than 15 centimeters below the soil surface. Seventeen of the remaining water-table plots indicated water tables 5 to 15 centimeters below the surface; 11

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[3] Permission to work on lands of the Quinault Indian Reservation, Simpson Timber Company, and Washington State Department of Natural Resources is gratefully acknowledged.

[4] R. H. Canfield. Application of the line interception method in sampling range vegetation. J. Forest. 39: 388-394, 1941.

[5] Water table depth (cm.) = 27.98 - 0.38X

$$\text{where } X = \frac{\text{Sum of petiole lengths (cm.) on entire intercept}}{\text{Length of intercept (m.)}} .$$

indicated water tables from 5 centimeters below the surface to above the surface. Although abundant Douglas-fir seed sources were present throughout the study area, only two Douglas-fir trees occurred on these 56 locations. Four other species were more adequately represented: red alder, western redcedar, Sitka spruce, and western hemlock (table 1). Their occurrence (presence of one or more trees of a given species at the same elevation as the line intercept) over various water tables is compared in figure 1 where species presence is shown without regard to vigor or growth. Although red alder and western redcedar were more frequently present than Sitka spruce and western hemlock over winter water tables less than 5 centimeters deep, occurrence of spruce and hemlock over more than 25 percent of these extremely shallow water tables indicates that all four species can survive in very wet areas. However, the western hemlocks had pale needles and were growing very slowly (less than 1 millimeter of radial growth per year).

Figure 2, showing only those trees growing 10 millimeters or more during 10 years, presents a better comparison of species. Red alder, western redcedar, and Sitka spruce are still relatively abundant over the shallowest water tables in figure 2, but western hemlock is absent. Healthy, well-growing hemlocks were not found where winter water tables were shallower than 5 centimeters.

When single radial growth measurements for each location were plotted over the estimated winter water-table depths for these locations (figs. 3, 4, 5, and 6), the influence of flowing ground water was immediately apparent. Radial growth of red alder and Sitka spruce was much greater over flowing water than over stagnant water where water tables were extremely shallow. Day[6/] recorded similar observations of Sitka spruce in British Columbia.

Locations with stagnant water tables were used in correlating radial growth and water-table depth for each species. These correlations were not significant for red alder and western redcedar; a logarithmic transformation of radial growth was significantly correlated to water-table depth for Sitka spruce and western hemlock. Apparently, water-table-depth differences were not related to growth differences in alder and cedar. Growth of spruce and hemlock decreased where stagnant water tables were nearer the soil surface.

Western hemlock and western redcedar seldom occurred over shallow water tables that were flowing--even where adjacent stands provided abundant hemlock seed sources. Both species were more common over shallow water tables that were stagnant, but hemlock grew very poorly there while cedar grew taller than any other species present.

[6/] W. R. Day. Sitka spruce in British Columbia, a study in forest relationships. Great Brit. Forest. Comm. Bull. 28, 110 p., illus., 1957.

Table 1.–*Estimated water-table depth, waterflow, tree species present, and tree measurements at each location*

Estimated water table depth *(centimeters)*	Water-flow	Tree species present[1]	Diameters and 10-year radial growth[2] of measured trees							
			Red alder		Western redcedar		Sitka spruce		Western hemlock	
			D.b.h.	Growth	D.b.h.	Growth	D.b.h.	Growth	D.b.h.	Growth
			Inches	*Milli-meters*	*Inches*	*Milli-meters*	*Inches*	*Milli-meters*	*Inches*	*Milli-meters*
Above surface	Stagnant	WRC, LPP	--	--	S	--	--	--	--	--
" "	"	WRC, WH, LPP	--	--	4	12	--	--	5	4
" "	"	WRC, SS, WH, LPP, WWP	--	--	S	--	S	--	S	-
" "	"	WRC, WH	--	--	S	--	-	--	S	--
" "	"	RA	S	--	--	--	--	--	--	--
0	"	RA, WRC	6	18	11	43	--	--	--	--
0	"	RA	7	10	--	--	--	--	--	--
1	"	RA, WRC	10	23	11	26	-	--	--	-
Above surface	Flowing	RA	7	60	--	--	--	--	--	--
" "	"	RA, SS	10	45	--	--	18	50	--	--
2	"	RA, WRC, SS	4	43	6	14	[illegible]	48	--	--
7	Stagnant	WRC, WH	--	--	18	22	--	--	SU	--
8	"	WRC, SS, WH, DF	--	--	13	14	17	4	14	-
10	"	RA,WRC	11	10	10	19	--	--	--	--
11	"	RA, WRC, WH	9	13	24	39	--	--	13	3
11	"	WRC, SS, WH	--	--	15	16	27	12	26	10
12	"	RA, WRC, WH	7	10	6	3	--	--	6	3
12	"	WH	-	--	--	--	--	-	8	4
12	"	RA, WRC, SS, WH	10	11	11	13	10	6	15	[illegible]
13	"	RA	12	8	--	-	-	-	--	--
13	"	WRC, SS, WH	--	--	4	10	3	5	4	5
13	"	WRC, WH	--	-	11	14		--	9	4
14	"	WRC, SS, WH	--	--	9	10	10	14	8	[illegible]
15	"	RA, WRC, SS, WH	12	4	16	28	10	9	15	7
15	"	WRC, WH	--	--	6	7	--	--	6	9
11	Flowing	RA	15	58	-	--	--	--	--	--
12	"	RA, SS	10	54	--	--	8	34	--	--
13	"	RA, SS, WH	4	28	--	--	4	38	4	34
16	Stagnant	RA, WH	6	8	--	--	--	--	8	10
17	"	RA	10	10	--	--	--	--	-	--
17	"	WRC, SS, WH	--	--	17	19	19	8	12	3
17	"	WH	--	--	-	--	--	--	3	10
17	"	WRC, WH	--	--	5	9	--	--	[illegible]	5
17	"	WRC, WH	--	--	8	15	--	--	8	10
20	"	WH	--	--	--	--	--	--	8	20
21	"	WRC, SS, WH	--	--	17	6	18	14	SU	--
21	"	RA, WRC, SS	9	17	9	20	6	18	--	--
21	"	RA	10	20	-	--	--	--	--	--
22	"	RA, SS, WH	SU	--	--	--	27	24	18	28
22	"	RA, WRC, SS, WH	SU	--	28	33	33	22	22	18
22	"	WRC, SS, WH	--	--	25	26	22	30	22	10
23	"	WRC, LPP	--	--	4	9	--	-	--	--
24	"	WRC, WH, LPP	--	--	6	14	--	-	6	16
25	"	WRC, WH, LPP, WWP	--	--	4	5	--	--	4	4
25	"	RA, WRC, SS	14	10	OM	--	OM	--	--	--
25	"	WRC, SS, WH	--	--	7	21	9	24	7	10
26	"	WRC, WH, WWP	--	--	16	40	--	--	15	15
26	"	WRC, WH	--	--	OM	--	--	--	6	9
26	"	WRC, SS, WH, DF	--	--	20	7	16	15	21	22
27	"	RA	9	34	--	--	--	--	--	--
16	Flowing	RA	14	18	--	--	--	--	--	--
16	"	RA, WH	9	28	--	--	-	--	8	32
20	"	RA, WRC, SS, WH	S	--	S	--	S	--	S	--
21	"	RA, WRC	9	35	S	--	--	--	--	--
24	"	RA, WRC, SS	3	27	3	15	3	6	--	--
24	"	WH	--	--	--	--	--	--	17	27

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[1] RA= red alder, WRC = western redcedar, SS = Sitka spruce, WH = western hemlock, LPP = lodgepole pine, WWP = western white pine, DF = Douglas-fir.

[2] Where diameters and radial growth measurements are absent, the trees were overmature (OM), suppressed (SU), or too small for increment boring (S).

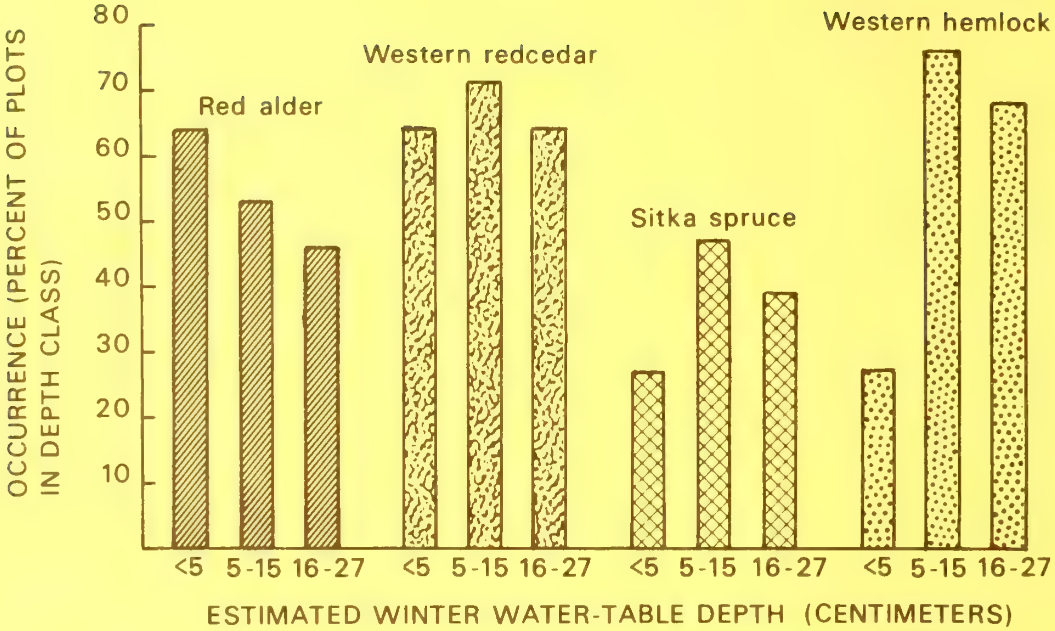

Figure 1.--Species occurrence over shallow water tables.

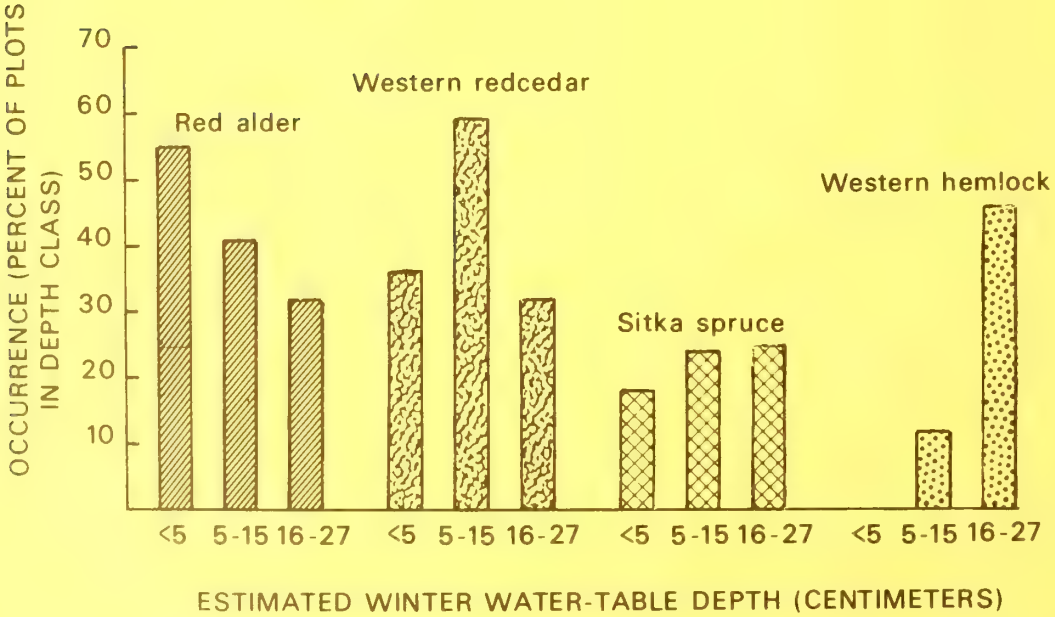

Figure 2.--Occurrence over shallow water tables of trees growing 10 millimeters or more in 10 years, by species.

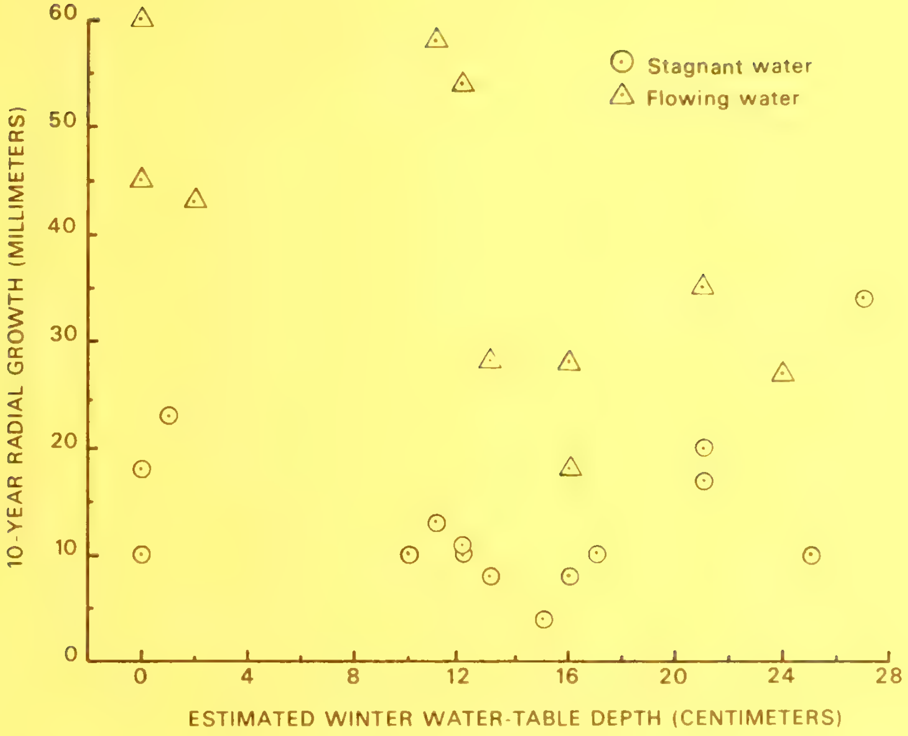

Figure 3.--Relation of radial growth of red alder to depth of winter water table.

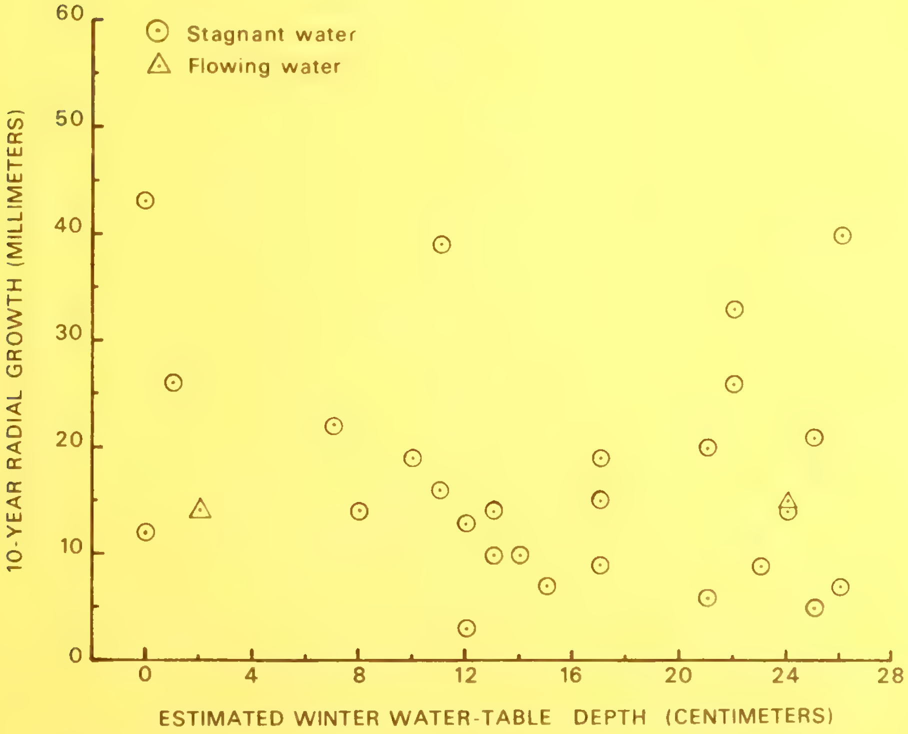

Figure 4.--Relation of radial growth of western redcedar to depth of winter water table.

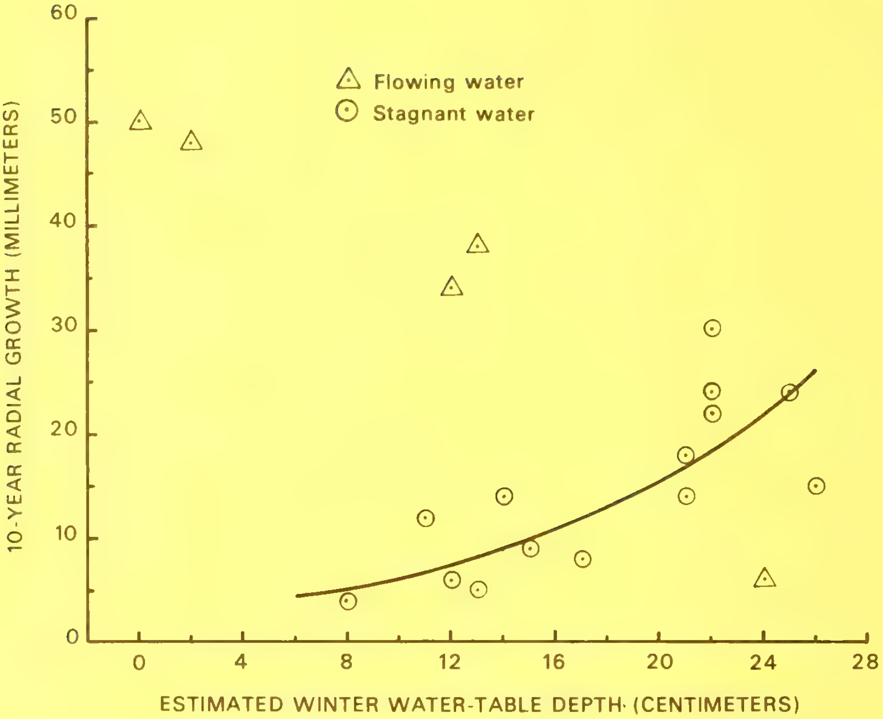

Figure 5.--Relation of radial growth of Sitka spruce to depth of winter water table.

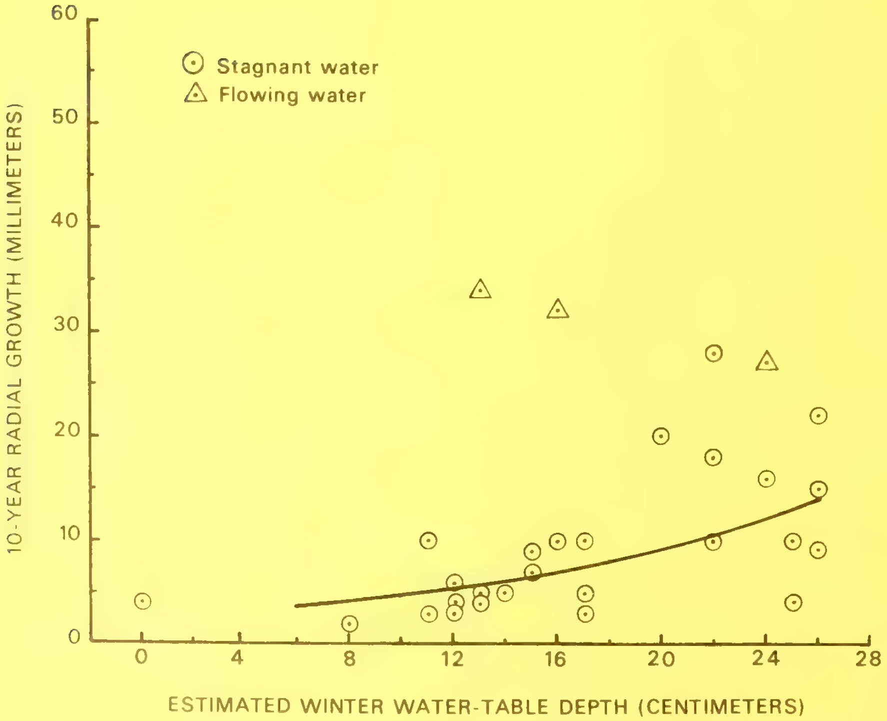

Figure 6.--Relation of radial growth of western hemlock to depth of winter water table.

Red alder and Sitka spruce were common over shallow water tables that were flowing. Both grew very well there, even where the winter water table was at or above the soil surface. Red alder was also common over shallow water tables that were stagnant. Sitka spruce was not.

DISCUSSION AND CONCLUSIONS

Data presented here were obtained from skunk-cabbage areas in one small portion of the Pacific Northwest. Although probably valid for other areas, these data and the following conclusions are strictly applicable only where skunk-cabbage occurs on or near the Olympic Peninsula.

The absence of Douglas-fir on wet areas, even where these areas were surrounded by Douglas-fir seed sources on drier sites, indicates that Douglas-fir cannot tolerate shallow water tables. However, the absence of lodgepole pine and western white pine does not indicate intolerance for shallow water tables because seed sources were not present for these two species.

Red alder, western redcedar, Sitka spruce, and western hemlock can all be considered adaptable to shallow water tables. All four seem able to tolerate winter water tables that are moderately shallow, and species differences are obscure where estimated winter water tables are more than 15 centimeters below the surface. Where water tables are less than 15 centimeters below the surface, the species respond differently to both depth and quality of the water table.

Red alder and western redcedar seem little affected by water-table depth, growing reasonably well even where stagnant water is near or at the surface during winter months. However, alder grows much faster where water near the surface is flowing. Sitka spruce also grows well where flowing water is near the surface. Spruce does not seem to tolerate stagnant water tables that are shallow, and it grows slowly where stagnant winter water is less than 15 centimeters from the soil surface. Western hemlock seldom occurs where flowing water is near the surface. It is quite common but grows very slowly where stagnant water tables are shallower than 15 centimeters.

Where estimated winter water tables of flowing water are shallower than 15 centimeters, red alder and Sitka spruce can be grown. Where the water is stagnant and within 15 centimeters of the surface, western redcedar or red alder are suitable species. Western hemlock should not be grown where estimated winter water tables are shallower than 15 centimeters.

The mission of the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is to provide the knowledge, technology, and alternatives for present and future protection, management, and use of forest, range, and related environments.

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PACIFIC NORTH WEST
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USDA FOREST SERVICE RESEARCH NOTE

PNW-161

August 1971

DEPRECIATIVE BEHAVIOR IN FOREST CAMPGROUNDS: AN EXPLORATORY STUDY[1]

by

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T., TECH. & AGR.

ABSTRACT

Vandalism, theft, littering, rule violation, and nuisance behaviors were studied in three campgrounds during 1968 using participant observation techniques. Information was gathered on the extent and character of such behaviors and factors associated with their occurrence. Empirical data based on structured observation schedules indicated a number of factors associated with depreciative behavior and possible methods of control.

Keywords: Camping, forest recreational use, recreation.

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[1] Revision of a paper presented to the Northwest Scientific Association, Cheney, Washington, March 22, 1969. Research reported in this paper was conducted under cooperative agreement between the Forest Service and the University of Washington's College of Forest Resources and Institute for Sociological Research.

INTRODUCTION

Human behavior which depreciates the physical and esthetic qualities of the environment in forest recreation areas is an important recreation management problem. Such depreciative behavior frequently results in the theft or damage of property and reduced quality of recreation experiences. Managers and others report rapidly increasing direct costs of replacing stolen or vandalized facilities and maintaining areas that have excessively deteriorated from careless or indifferent use. Less tangible but equally important are the indirect costs of depreciative behavior. Defacement of the natural environment, excessive noise, nuisance behavior, and a variety of major and minor rule violations all detract from recreationists' experiences.

This study was an attempt to: (1) explore--using participant observation techniques--the nature, extent, and possible causes of campground behavior problems and their solutions, and (2) sensitize the researchers to such problems to facilitate designing a larger study (Campbell 1970, Campbell, Hendee and Clark 1969). No specific hypotheses were tested during this study.

Data reported here were collected at Lake Kachess campground in the Wenatchee National Forest, although supplementary data were also collected from Kalalock campground in Olympic National Park and from Lake Chelan (Washington) State Park. Each of these campgrounds is characterized by heavy use, highly developed facilities, opportunity for water-oriented activities, and the presence of resident Rangers.

RESEARCH METHODS

Systematic participant observation techniques were used to record depreciative behavior without disturbing campers or influencing their actions (Campbell 1970). During the summer of 1968, a team of participant observers camping at the study locations mingled unobtrusively with other campers in selected portions of the campgrounds and systematically noted specific information on all depreciative behavior observed. The data collected included a description and classification of the observed depreciative acts, personal characteristics of the offenders, the apparent cause or motivation for the acts, the reaction of others affected and of nearby campers, official action taken, and the apparent results. The data reflect observed behavior, systematically collected and recorded throughout the range of environments available in the intensively developed campgrounds studied.

In addition to several 1/2-hour scheduled observation periods each day, morning and evening inspections of the campground were conducted. Information was also collected from campground Rangers on other depreciative incidents coming to their attention. Data were collected on more than 400 depreciative acts in the Lake Kachess campground.

The depreciative acts were classified as follows:

Nuisance acts reflected behavior essentially a bother or annoyance to other campers which might or might not violate campground rules or other legal restrictions. Examples are excessive noise, violations of privacy (such as unsupervised children running through other parties' camps), and intentionally freeing pets to roam the campground.

Vandalistic acts included deliberate, destructive or defacing acts committed against private property, campground facilities, or the surrounding environment.

Legal violations were acts which violated campground rules, traffic regulations, and local or State laws.

In the following account, some observed patterns of depreciative behavior involving nuisance acts, vandalism, and legal violations in the Lake Kachess campground are described. Some basic questions considered are: What types of depreciative acts occur and how often? Who commits them? What were offenders doing when the act was committed? What was the apparent reason for the act? Who was affected by the behavior, and how did they react? What official action was taken? How did offenders respond? Answers to these questions are basic both to further study of depreciative behavior and to the design of procedures to control such behavior.

DISCUSSION

Types of Depreciative Acts Observed

A wide range of depreciative behavior was observed (table 1). Nuisance acts were the most common type and accounted for 50 percent of all depreciative acts reported. Legal violations were the next most frequent, accounting for about 37 percent, followed by vandalistic acts making up 13 percent of the incidents recorded. Of the nuisance acts observed, almost 80 percent involved pets which were allowed to run loose in the campground or on the beach. The remainder included excessive noise, violations of privacy, sanitary offenses, and hazardous behavior such as throwing rocks in the swimming area when swimmers were present.

Most legal violations involved campground rules, followed by traffic violations and littering. Only a handful of civil law violations was observed. Recorded theft was relatively infrequent but involved expensive items.

About 60 percent of the vandalistic acts were directed at campground facilities, and only 30 percent involved the natural environment. Public, not private, property was usually the target of vandals in the cases observed.

Table 1.--*Types of depreciative acts observed*

Depreciative act	Number	Percent[1] [2]
Nuisance acts:		
Excessive noise	12	5.8
Health hazard	12	5.8
Unesthetic	6	2.9
Violations of privacy	12	5.8
Pets	166	79.8
Total	208	100.1 (49.9)
Vandalism:		
Private property	5	9.1
Campground facilities	34	61.8
Natural environment	16	29.1
Total	55	100.0 (13.2)
Law violations:		
Campground rules	72	46.8
Traffic rules	45	29.2
Civil laws	2	1.3
Theft	4	2.6
Littering	31	20.1
Total	154	100.0 (36.9)
Total depreciative acts	417	100.0

---

[1] Numbers in parentheses are percentages of "total depreciative acts."

[2] Percentages may not total 100.0 percent due to rounding.

Offenders

There was no clear pattern in the frequency of depreciative acts committed by different types of users (table 2). When it was possible to identify the offenders, it was found that tent campers, trailer campers, and pickup-truck campers committed depreciative acts in roughly the same proportions as they appeared in the campground. Nearly 20 percent of the acts identified by type of visitor were committed by day users, but there was no basis for determining their proportionate attendance in the campground.

Table 2.--*Types of depreciative acts committed by different types of campers*

Depreciative act[1]	Tent campers (N=32)	Trailer campers (N=46)	Pickup truck campers (N=16)	Day users (N=21)
	Percent[2]			
Nuisance acts	31.3	10.9	12.5	23.8
Vandalism	12.5	17.4	12.5	9.5
Rule violations	56.3	71.7	75.0	66.7
Total depreciative acts[3] [4]	100.1 (26.4)	100.0 (38.0)	100.0 (13.2)	100.0 (17.4)

[1] Only those depreciative acts for which "type of camper" could be determined were included in this table.

[2] Numbers in parentheses are percentages of "total depreciative acts."

[3] Five percent was attributed to "other" types of users not included in this table.

[4] Percentages may not total 100.0 percent due to rounding.

The classification of acts committed by different types of users did vary (table 2). For all types of users the most common depreciative acts recorded were rule violations; but these were less frequent among tent campers, who at the same time were reported to commit the highest proportion of nuisance acts.

One unpredicted finding was that there appeared to be no strong relationship between age of camper and incidence of depreciative acts, although age groups differed somewhat in the types of acts committed (table 3). According to our observations, teenagers most often violated campground rules, including traffic regulations, and were less likely than adults or children to commit nuisance acts.

Table 3.--*Types of depreciative acts committed by different age groups*

Depreciative act[1]	Adults (N=197)	Teenagers (N=66)	Children (N=82)
	- - - - - - - - - -	*Percent*[2]	- - - - - - - - - -
Nuisance acts	47.7	27.3	53.7
Vandalism	4.6	4.5	19.5
Law violations	47.7	68.2	26.8
Total depreciative acts	100.0 (57.1)	100.0 (19.1)	100.0 (23.8)

[1] Only those depreciative acts for which "age group" could be determined were included in this table.

[2] Numbers in parentheses are percentages of "total depreciative acts."

Children, usually while playing in groups of two or three, were most likely to commit acts of vandalism which were directed primarily at campground facilities. But, the most frequent type of inappropriate behaviors for children were nuisance acts--most often involving pets and violations of privacy.

Adults were most likely to commit nuisance acts or violate rules. When adults were observed in vandalistic acts, they usually involved the natural environment rather than campground facilities, which were the target of children; and these adult acts involved individuals rather than groups.

Activities Associated With Depreciative Acts

As previously noted, vandalism frequently involved children, which raises a pertinent question. To what extent can such vandalism be regarded as malicious on the part of children? The data indicated that almost all vandalism carried out by children occurred during play. Consequently, boredom, carelessness, or lack of understanding of consequences may be a more important element in certain kinds of vandalism than is malice.

On the other hand, vandalistic acts of adults were often associated with camp chores where appropriate behavior stymied their completion. For example, adults gathering wood often damaged both natural environment and camp facilities. Here, indifference to consequences and to inconvenient laws may be the primary determinant of vandalism among adults.

Finally, approximately one-third of all vandalistic acts occurred while campers were actually attempting to enjoy the natural environment (table 4). The target was most often campground facilities rather than the natural environment, which campers attempted to manipulate inquisitively or to facilitate their activity. For example, interpretive signs and fences on the nature trail were often damaged when parents allowed their children to climb on them.

Table 4.--*Associated activity when depreciative acts were committed*

Depreciative act[1]	Entertainment	Camp chores	Nature study	Social interaction	Moving through camp	Total[2]
	Percent					
Nuisance acts (N=111)	52.3	4.5	4.5	20.7	18.0	100.0
Vandalism (N=28)	39.3	25.0	35.7	0	0	100.0
Law violations (N=132)	27.3	33.3	1.5	10.6	27.3	100.0
Total depreciative acts (N=271)	38.7	20.7	6.3	13.7	20.7	100.1

[1] Only those depreciative acts where "associated activity" could be determined were included in this table.

[2] Percentages may not total 100.0 percent due to rounding.

This general pattern held for rule violations and nuisance acts, that is, they were committed incidental to other activities such as doing camp chores, playing, or walking through the campground. Campers involved in such chores as setting up camp or disposing of waste materials frequently violated campground rules. Littering occurred while people were walking through camp, sunbathing or swimming, or during social interaction with other campers.

Traffic violations usually involved motorbikes rather than cars, and usually during their use for sport rather than for necessary transportation. Pets were often unleashed to accompany campers on a walk or to ease the burden of tending to them.

Reasons for Committing Depreciative Acts

The observed depreciative acts are classified in table 5 as to their apparent motivation, i.e., whether they appeared to be committed for entertainment, for convenience, as sheer disregard for rules and effects on others, due to ignorance of rules, or because rules interfered with some desired goal. Most of the nuisance acts, especially those involving pets, stemmed from ignorance of rules; but others, such as excessive noise, violations of privacy by children, and rock throwing, appeared to be deliberate disregard of the effects on others.

Table 5.--*Apparent motivation for depreciative acts*

Depreciative act[1]	Entertainment	Convenience	Disregard	Ignorance	Rules interfere with goal	Total[2]
	Percent					
Nuisance acts (N=119)	16.0	5.0	14.3	64.7	0	100.0
Vandalism (N=31)	32.3	6.5	45.2	16.1	0	100.1
Law violations (N=120)	16.7	10.0	47.5	6.7	19.2	100.1
Total depreciative acts (N=270)	17.9	7.3	33.3	33.3	8.4	100.2

[1] Only those depreciative acts where "apparent motivation" could be determined were included in this table.

[2] Percentages may not total 100.0 percent due to rounding.

Vandalism of camp facilities most often reflected disregard, but almost one-fourth of these acts seemed to be for entertainment. On the other hand, vandalism of the natural environment, such as chopping on trees in the campground, was most often for entertainment and to a lesser extent due to ignorance of rules or the consequences of the act.

Rule violations were usually the result of sheer disregard of known regulations and are illustrated by littering. However, there were a number of incidents where rules were violated because they interfered with other desired goals. For example, a full campground often invited camping in the picnic area, and visiting friends often resulted in more than one group at a campsite.

Campground facilities, the natural environment, and people all suffered from the depreciative behavior observed (table 6). Nuisance behavior, by definition, affected people almost exclusively.

Table 6.--*Victims of depreciative acts*

Depreciative act	People	Private property	Public property	Natural environment	Rules	Total[1/]
	- - - - - -	- - - -	- - - -	*Percent* - - - -	- - - -	- - - -
Nuisance acts (N=204)	98.0	0.0	1.0	0.5	0.5	100.0
Vandalism (N=51)	0	2.0	66.7	31.4	0	100.1
Law violations (N=146)	21.9	2.1	1.4	44.5	30.1	100.0
Total depreciative acts (N=401)	57.7	1.0	9.5	20.4	11.4	100.0

[1/] Percentages may not total 100.0 percent due to rounding.

Two-thirds of the time, vandalism affected campground facilities. Of the remaining, almost one-third was of the natural environment, with private property involved in very few cases.

Rule violations, especially littering, impinged on the natural environment in almost half the cases; but in another third, objection to the rules themselves seemed to be the object of the act--especially campground and traffic rules which campers did not seem to think were legitimate. Violation of civil, traffic, and campground rules impinged directly upon other people in about 20 percent of the cases recorded.

Reactions of Bystanders

More than 80 percent of the depreciative acts observed were committed when other people were around (table 7). In more than 90 percent of these

Table 7.--*Reaction of bystanders to depreciative acts*

Depreciative act[1]	No one around	Approved of act	No reaction	Ignored act	Commented to others	Notified Ranger later	Notified Ranger immediately	Confronted offender	Total[2]
	- - - -	- - - -	- - - -	- - - -	- - - Percent	- - - -	- - - -	- - - -	- - - -
Nuisance acts (N=197)	9.1	0.5	78.7	2.5	4.6	0.5	0.0	4.1	100.0
Vandalism (N=34)	52.9	0	44.1	0	0	0	2.9	0	99.9
Law violations (N=140)	17.9	1.4	65.7	4.3	8.6	.7	.7	.7	100.0
Total depreciative acts (N=371)	17.1	.8	70.1	2.9	5.6	.5	.5	2.4	99.9

[1] Only those depreciative acts for which "reaction" could be determined were included in this table.

[2] Percentages may not total 100.0 percent due to rounding.

cases, no perceptible reaction by adjacent campers could be observed. People either ignored or were indifferent to the act or did not see anything happen.

In the small percentage of cases where there was some reaction by onlookers, they most commonly commented to other people about the incident. In a few cases, people were obviously upset but took no action. Even when acts of vandalism were committed in view of adjacent campers, remedial action was observed only once. In this case, the camper summoned a Ranger.

In total, other people were impinged upon in about 60 percent of all depreciative incidents observed. But, it appears that their indifferences creates a climate where depreciative behavior can and will occur with little consequence to the offender.

OFFICIAL ACTION--OFFENDER'S REACTION

Rangers were in the immediate vicinity during less than 90 percent of the depreciative incidents observed. This was undoubtedly due to the fact that they had a large territory to cover. Data are insufficient to support or reject the notion that the presence of Rangers is a deterrent to depreciative behavior, although it is logical that this is true. In the few occasions Rangers were present, they took one of four steps, varying with the seriousness of the act. They either did nothing or reacted by attempting to educate the offender, warning him not to repeat the act and making him rectify the situation, or issuing a citation.

In most cases where a Ranger did act, the offender was cooperative. Indifferent or uncooperative behavior was infrequent and only when the offender was reprimanded for violation of campground rules. In these cases, violators complied with the Ranger's instructions about two-thirds of the time. Repetition of the act was more common than was complaining after confrontation with the Ranger and usually was associated with violation of campground and traffic rules. It appeared that repeated violation reflected camper judgments that the rules were either unnecessary or interfered with other recreational activities or goals.

IMPLICATIONS OF THE DATA

Depreciative acts are apparently committed for a variety of reasons; and several approaches seem logical for their control, including better communication of rules, educational programs to increase the campers' awareness of the consequences of certain acts, and stricter enforcement of regulations. The data suggest, contrary to some prevailing opinion, that depreciative behavior is not always the result of "slobism" (Frome 1969) or vandals running wild (Bennett 1969) in outdoor recreation areas.

These observations indicate that all campers share responsibility for depreciative behavior. Again, contrary to popular belief evident in some popular literature (Bennett 1969), teenagers did not commit a disproportionate amount of depreciative acts. Instead, preteenage children in groups of two or three appeared to be the primary cause of much expensive damage to facilities. This suggests that stricter supervision of children by parents might eliminate much of the expensive vandalism.

The data suggest that rules intended to control certain types of unwanted behavior in campgrounds must be clearly analyzed as to their specific intent and their effects on recreational activity before they are put into effect. If the public cannot see their worth and underlying rationale, then they will most likely be violated. The public needs to be educated as to why there are rules and why depreciative behavior is inappropriate in campgrounds.

Finally, the data indicate that people will cooperate when challenged by a Ranger if he explains the situation. It seems likely, therefore, that the public will support attempts to reduce depreciative behavior if it understands the underlying reasons.

FUTURE RESEARCH

As indicated early in this paper, these results are suggestive--not conclusive. The objective was to sensitize the researchers to campground behavior problems by collecting systematic, but not necessarily representative, data describing the character of depreciative behavior in a forest campground. Such data are useful in formulating propositions, hypotheses, and generalizations to be tested in further research. In addition, in many cases, the data collected contradict prevailing folklore and belief about the nature and cause of campground depreciative behavior.

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3P SAMPLE LOG SCALING

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ABSTRACT

An application of the 3P sample selection procedure to sample log scaling is described in this report along with results from three tests. The method looks promising for some situations, and it may prove superior to the sample log scaling methods now in use.

Keywords: Log scaling, sample designs (forestry), timber estimating, defect deduction (merchantable volume), forest measurement.

REST SERVICE - U.S. DEPARTMENT OF AGRICULTURE - PORTLAND, OREGON

INTRODUCTION

The 3P sample selection procedure,[1] which was originally developed for timber cruising, has been applied to log scaling with results which appear to be promising. This application was tested first in Idaho[2] and later in Oregon. Results of the Oregon test will be described in this report along with details of procedure.

Under this procedure the scaler quickly guesses the small-end diameter and length of each log in the group of logs for which an estimate of total volume is required. The two guesses are then translated to gross log volume in terms of the Scribner Decimal C log rule, and "guessed" gross volume is compared with a random number from a specially prepared set of random numbers.

If the random number is greater than guessed gross volume or if the random number is zero, the guess is merely recorded and the log is passed by. If the random number is less than or equal to the guess, but not zero, the log is carefully scaled for both gross and net volume.

The largest number in the set of random numbers should be at least as large as the largest guessed log volume. Since each number from one to the largest will tend to be equally frequent in the set, the number of random numbers which will qualify any log for the sample will tend to be proportional to the guessed volume of that log. This follows from the sample selection rule given in the previous paragraph. If the set were infinitely large, the number frequencies would be exactly equal and the proportionality would be absolute. In other words, there will be about twice as many numbers available for qualifying a log with a predicted volume of, say, 400 board feet as for a log with a predicted volume of 200 board feet. A 1,000-board-foot log will tend to have 10 times as many qualifying numbers, and therefore 10 times as many chances of getting into the sample as will a 100-board-foot log. The frequency of zeros in the set of random numbers will be more or less large depending on the desired sample size.

Obviously, large logs are favored under 3P sample selection, and this must be compensated for. The compensation is accomplished by taking the ratio of scaled volume to guessed volume for a sample log as the observation which has unit weight, and then multiplying the average of all such ratios by the sum of the guessed volumes for all logs in the group.

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[1] L. R. Grosenbaugh. Some suggestions for better sample tree measurement. Proc. Soc. Amer. Forest. Meet. Oct. 20-23, 1963, Boston, Mass., p. 36-42, 1964.

[2] Speech presented by James C. Space, Supervisory Forester, Sandpoint Ranger District, Kaniksu National Forest, West. Pine Reg. Log Scaling Soc. Ann. Meet., Coeur d'Alene, Idaho, Oct. 9, 1969.

Thus

$$V = (\overset{n}{\Sigma} R/n)(\overset{N}{\Sigma} KPI)$$

where V = estimated total scaled volume (net or gross) for a group of logs,

KPI = guessed volume of one log by the Scribner Decimal C log rule.

$\overset{N}{\Sigma} KPI$ = sum of guessed volumes over all logs in the group,

N = number of logs in the group,

R = measured volume divided by guessed volume for one sample log,

$\overset{n}{\Sigma} R$ = sum of R over all sample logs in the group,

and n = number of sample logs in the group.

If the groups of logs being sampled by one set of random numbers have been divided into subgroups (strata), the above equation will apply only to the logs in a single stratum. In that event, estimated total volume for the entire group of logs (all strata) is obtained simply by adding estimated stratum volumes.

THREE TESTS

Three tests of 3P sample log scaling were made recently. In two of these tests, the logs were in rafts and in the third the logs were on trucks. Scaling procedures used on all three tests were those prescribed for National Forest timber sales in western Oregon and western Washington. There were three species in the truck test, and each species was identified as a separate subgroup or stratum. Each of the two raft tests consisted of a single stratum.

RANDOM NUMBERS

Random numbers created for the truck test are illustrated in figure 1. These numbers are comparable to guessed log volumes by the Scribner Decimal C log rule. For example, a log with a 300-board-foot guessed volume would

Figure 1

```
RANDOM NUMBERS FOR TRUCK TEST                                PAGE    1    07/29/71
L=    762522741, LIM= 1500, K=  300, KZ=  440                          TRUK

      0    223     62    131      1    270    239      0    209     77
    271      0      0      0      0      0      0     17     10      0
    232    177      0    141    128     13    141     36     15      0
      0      0     61     78    213    182    140     41     98    283
      0    293    294     78    128    136    208    141      0     78
      0     10      0    295     41     83    209      0      0      0
     83     39      0      0      0     96    170      0      0     45
      0    134    222     98     10    150    102     57      0      3
    110    204      0     67     41     74    119      0     19    114
    186    183    241    201      0      0    162    213      0    124
    270    126     32      0    118      0      0    232      0      0
      0     54      0     24      0    198      0     63    253      0
    292      0     54    110      0      0     25    162    116      0
    219    132      0    237    202      0    223    129      0      0
     72    224    113     18     46      0    124    118      0      0
      0      0      0    177      0     91    252    107    140    163
    167      0    196      0      0      0    198    282      0    116
      0     55    224      0    256      7    156      0    255      0
      0      0    158     68      0    149    286     90     70      0
    163    252      0    203    186    145     83      0     87    267
    107    257    187     80    256    217     82      0     70      0
      0    101    240    201      0    223     67      0    174    123
     90     31      0    218      0     46      0      0    129    150
    183      0    142      0      0     87     77    266      0      0
      0    233     42      0    233    120      0      0     77    194
    202    144      0    245      0     27      0    107    149    150
      0      0      0    139     20      0    166    239     10      0
      0    137     61     68    145    143      0      0      0      0
      0    221      5    206    146      0      6     26    246    179
      0      0    102    243    193    194    143      0     28    156
      0      0      0    231    118    161      0    190     93      0
    164    207      0    298      0    277    192      0    198    135
    278     44      0      0    257    197      0    274      0      0
    214    293    288      6      0    157      0      0     10     51
      0      0    120      0      0    124    292    283    239    145
     43      0    244     45    100    298    148      0    286    139
      0    292    222    150      0      0     67      0    238      0
     95     75    111    254      0    197    201    162     88    298
    252    217      0    114    182    274      0    179     33    247
      0     96    257    285    116      0    148     23    152    191
      0      0      0    136     71     93    260      0     45      0
     29     25     51     96     15      0      0      0     12      0
      0    138      0      0    130    298    125     48     49      0
     62    158     44    288      0      0      0    106    177     10
    197     32     91      0      0      0     50     10    240    156
    137      0      0      0    266     84     67      0    140    114
      0    173    239    123    107      0    224    109      2      0
      1      0     56      0    136    160    298     46      7      0
    165    203     63    234    118    192    218    170     31    284
      0    219    146    131      0      0    167    111     71      0
                                                                           46983
   TRUK   TRUK   TRUK   TRUK   TRUK   TRUK   TRUK   TRUK   TRUK   TRUK       327
```

be coded 30, and any random number from 1 through 30 would qualify that log for the sample of precisely measured logs. The coded guessed volume of a log will be called KPI following Grosenbaugh's notation.

A computer program called THRP[3] is used to create the random number sets. This program requires only three items of information:

1. An advance estimate (K) of the gross volume of the largest log in the entire group of logs that is to be sampled (i.e., including all strata) with one set of numbers. This advance estimate cannot and need not be precise. An overestimate is better than an underestimate. If the timber to be scaled had been previously cruised, the cruise data are a likely source for this advance estimate.

2. An advance estimate of the total gross volume in all of the strata which are to be sampled with one set of random numbers. Information from a timber sale cruise could be used for this advance estimate. This advance estimate is an attempt to anticipate the eventual sum of the guessed volumes $(\overset{N}{\Sigma} KPI)$ over all logs in all strata. If an estimate is inaccurate, the only penalty will be that the sampling error for the eventual estimate of total volume (all strata) will be either greater or less than desired.

3. An advance estimate of the total number of logs in all strata. This merely tells the computer how many numbers to produce. Since the numbers are inexpensive, there is no harm in using a rather large overestimate.

Item 2 must be divided by an arbitrary value for n (i.e., expected number of sample logs in all strata that will be sampled with one set of random numbers). The quotient (called KZ) is then punched on a THRP control card along with items 1 and 3. The arbitrary value for n will depend on the level of precision (i.e., size of the standard error) required for the eventual estimates of total sale volume (all strata) and on the expected average within-stratum coefficient of variation for R, the ratio of measured to guessed volume. Initially, the choice of n will be difficult, but it will become easier as experience accumulates over many samplings.

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[3] L. R. Grosenbaugh. Three-pee sampling theory. USDA Forest Serv. Res. Paper PSW-21. Berkeley, Calif., Pac. Southwest Forest & Range Exp. Sta., 53 p., 1965.

DATA

The tally form and tallied information for 31 of the 266 logs in the truck test are shown in figure 2 to help describe the 3P procedure.

Thirteen spaces in the heading of the tally form have been allocated to an identification of the entire group of logs which are being sampled with a single set of random numbers. A single job could be an entire timber sale, or any portion of a timber sale (e.g., logs sold in a month or a quarter), or a single raft. At least one of these spaces must be used with a distinctive code.

Information from each log in a timber sale will be recorded on a single row in the body of the form. The word "log" as used here refers to any whole log 40 feet or under and to scaled segments of whole logs which are longer than 40 feet.

Columns headed "log identification" may be left blank, or they could be used for a truck number, log number, or any remarks pertinent to an individual log that a scaler might care to make. Entries in these columns will not be used in the subsequent processing of data.

A distinctive stratum code must be used to identify the logs for which separate estimates of total volume are required. Usually each species will constitute a stratum; but a stratum can include several species, and there can be more than one stratum per species (e.g., sound and defective Douglas-fir). Stratum codes can be any combination of alpha or numeric characters.

A code = in the third column means that the log in question will not be part of the sample and will be scaled without question. It will be called a "sure" log following Grosenbaugh. This would be appropriate whenever there are only a few logs in a stratum or whenever the logs in a stratum are of such high value that any amount of sampling error would be intolerable. An asterisk (*) in this column means that the log in question is part of a group of logs being sampled and has been selected for precise measurement. If the third column is blank, the log is part of the group of logs being sampled but was not selected.

Columns headed *KPI* are for the coded guessed volumes of those logs which are sampled. There must be an entry in these columns whenever there is an asterisk (*) in the preceding column or whenever the preceding column is blank. These columns can be left blank whenever the code = appears in the preceding column. However no harm will be done if a *KPI* is entered for a "sure" log because it will be ignored by the computer. If the *KPI* for any log happens to be larger than K, the advance estimate of largest *KPI* that was used

Figure 2

3P SAMPLE LOG SCALING
SALE IDENTIFICATION

TRUCK TEST

LOG IDENTIFICATION	STRATUM	* =	KPI	GROSS		NET	
				L	D	L	D
4656	DF		86				
4656	DF		53				
4656	DF	*	186	40	34	32	33
4656	DF		15				
4656	DF		65				
4656	DF		129				
4656	DF		13				
4656	DF		56				
4656	DF		49				
2118	DF		6				
2118	NF		7				
2118	NF		5				
2118	DF	*	76	40	18	40	18
2118	DF		10				
2118	DF		9				
2118	DF		15				
2118	DF		7				
2118	DF		29				
2118	DF		12				
2118	DF		7				
2118	DF		70				
2118	DF		5				
2118	DF		20				
2118	DF		34				
2118	DF		32				
2118	DF		49				
4304	DF		53				
4304	DF	*	53	36	18	36	18
4304	DF		40				
4304	DF		66				
4304	DF		23				

to create the random numbers, the scaler may either reduce this *KPI* to *K* before comparing it with a random number, or he may call the log, "sure."

Gross and net lengths (L) and diameters (D) are for individual logs or for segments of whole logs which are over 40 feet long. Each segment of a whole log which is over 40 feet will be treated separately in the sample selection process. Thus entries will be made on two rows of the tally form for a two-segment-long log, and either one or both of these segments may become part of the sample. A sample log will be distinguished from a nonsample log by entries in the L and D columns. All "sure" logs will, of course, have entries in the L and D columns.

Defect deductions leading to the lengths and diameters in the net columns of the tally form were made according to National Forest scaling practice for western Oregon and western Washington.

Twenty-eight of the 31 logs listed in figure 2 are obviously nonsample logs, since nothing is recorded for them in the L and D columns. There were no "sure" logs in the truck test.

Information on the tally forms is punched on cards with one card per row of information. Cards are then sorted by stratum. Decks for several strata and for several jobs can be stacked and processed in one computer run by a program called SLOT which was written for the CDC 6400 computer.

OUTPUT SPECIFICATIONS

Output from SLOT is in two parts. The first part (see fig. 3) is simply a listing of information on individual sample logs and on individual "sure" logs, if any. There will be a separate listing for each stratum. Figure 3 shows only the listing for the Douglas-fir stratum of the truck test.

A portion of the information listed is simply a relisting of input data from the tally form, but gross and net Scribner volumes, as selected by the computer, are also shown along with the ratios (*R*) of measured to guessed volumes and with an expansion factor for each log. If the volume of a log is multiplied by this factor and if the products of this multiplication for all sample logs in a stratum are added, the result will be estimated total volume for the sampled portion of that stratum. A simple sum of the volumes of "sure" logs in a stratum added to the estimated total volume for the sampled portion of the stratum will equal the estimated total volume in the entire stratum.

Figure 3

```
                     S L O T          3P LOG SCALING   WEST SIDE

INFORMATION ON 3P AND SURE LOGS BY STRATUM                                                 07/21/71

STRATUM IDENT           DF                  PAGE    1                 NUMBER OF KPI LOGS    224
SALE IDENT       TRUCK TEST

  LOG IDENTIFICATION    KPI    GROSS      NET        VOLUME      DEFECT       R            EXPANSION
                               L   D     L   D     GROSS NET     VOL.    GROSS   NET         FACTOR
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

             4656       186    40  34    32  33     20C  157      43     1.075  .844         2.573
             2118        76    40  18    40  18      53   53       0      .697  .697         6.298
             4304        53    36  18    36  18      48   48       0      .906  .906         9.031
             3610        24    16  20    16  17      28   18      10     1.167  .750        19.944
             4162        84    40  20    36  20      70   63       7      .833  .750         5.698
             3942        60    40  19    40  16      60   40      20     1.000  .667         7.978
             3942        19    4C  14    40  13      29   24       5     1.526 1.263        25.193
             2796       106    34  24    34  23      86   80       6      .811  .755         4.516
             2796       100    2C  34    20  31     10C   89      11     1.000  .890         4.787
             2796        61    17  31     8  31      75   36      39     1.23C  .590         7.847
             6639        49    40  17    40  17      46   46       0      .939  .939         9.769
             4656        18    34  13    34  12      21   17       4     1.167  .944        26.593
             1024        89    24  21    24  18      46   32      14      .517  .360         5.378
             1024       200    40  34    40  32     200  184      16     1.000  .920         2.393
             1025       142    40  27    20  27     137   68      69      .965  .479         3.371
             1025        89    38  20    38  16      66   38      28      .742  .427         5.378
             2798        76    38  22    34  20      79   60      19     1.039  .789         6.298
             2798        51    34  19    34  15      51   30      21     1.00C  .588         9.386
             1027        23    26  17    24  16      3C   24       6     1.304 1.043        20.812
             1027       103    36  24    36  20      91   63      28      .883  .612         4.647
             1027        64    22  26    20  26      69   62       7     1.078  .969         7.479
             1027       217    38  34    36  33     190  176      14      .876  .811         2.206
             2121       176    36  33    34  33     176  167       9     1.00C  .949         2.720
             1C28       300    4C  4C    38  38     300  254      46     1.00C  .847         1.596
```

The equation for estimated total stratum volume (see page 3) can be rewritten to clarify the expansion factors for individual logs:

$$V = \left[y_1 \frac{\overset{N}{\Sigma KPI}}{KPI_1 n} + y_2 \frac{\overset{N}{\Sigma KPI}}{KPI_2 n} \text{- - - - - - - - - - - - -} + y_n \frac{\overset{N}{\Sigma KPI}}{KPI_n n} \right]$$

where y_i = scaled volume for an individual sample log.

Thus, the expansion factor for the first log in figure 3 can be calculated by taking ΣKPI for the DF stratum in figure 4 (11,488) and dividing it by the DF sample size in figure 4 (24) and again by the KPI for the first log (186):

$$\frac{11,488}{(24)(186)} = 2.573.$$

Part 2 of the SLOT output contains summary information for the entire sale (see fig. 4). The sums of *KPI* in the farthest right column of this output are for all logs (sample + nonsample). Equations used for calculating coefficients of variation and standard errors shown in figure 4 are given in the appendix. Estimated total volumes are expressed in units of 10 so the net estimate for Douglas-fir is 89,930 board feet. Defect percentages are simply differences between gross and net total volumes expressed as a percent of gross total volume.

Summary information for the two raft tests is shown in figures 5 and 6. There were three "sure" logs in one raft test (fig. 5). They were called "sures" because they appeared to be excessively defective. Had they been selected for the sample, they might have had very low volume/*KPI* ratios. This would have increased coefficient of variation and sampling error for the net volume estimates considerably. If there are likely to be many logs that are highly defective, it might be better to put them in a different stratum and to sample that stratum rather than scale all the logs as "sure." Thus, there could be a Douglas-fir stratum (DF) and a defective Douglas-fir stratum (DDF).

Lower coefficients of variation and therefore lower standard errors might have resulted if the *KPI*'s had been in terms of net rather than gross log volume. However this could lead to bias since the scaler's judgments regarding defect in his scaling of the logs selected for the sample might be conditioned by the quick judgments he made while applying his *KPI*'s. *KPI* and scaled volumes on individual logs must be independent.

Figure 4

```
                              S L O T           3P LOG SCALING   WEST SIDE

SUMMARY FOR SALE                                                                                          07/21/71

      SALE IDENT      TRUCK TEST        PAGE    1

    STRATUM       SAMPLE          G R O S S                            N E T                     DEFECT      TOTAL      SUM OF KPI
                   LOGS   VOL.DC        SE        CV        VOL.DC        SE        CV                      LOGS
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

      DF      3P    24    11371       4.27     20.93          8993      5.41     26.52           20.907       224       11488
            SURE     0        0                                  0                                0.000         0
           TOTAL          11371       4.27                    8993      5.41                     20.907       224

      WP      3P     3      291      13.21     22.88           287     14.65     25.37            1.258        10         329
            SURE     0        0                                  0                                0.000         0
           TOTAL            291      13.21                     287     14.65                      1.258        10

      NF      3P     3      982      12.36     21.41           787     11.51     19.93           19.924        32        1224
            SURE     0        0                                  0                                0.000         0
           TOTAL            982      12.36                     787     11.51                     19.924        32

      SALE TOTAL          12644       3.97     21.28         10067      4.94     26.21
```

Figure 5

```
                                          S L O T           3P LOG SCALING   WEST SIDE
SUMMARY FOR SALE                                                                                                        07/26/71
        SALE IDENT       RAFT 639C        PAGE    1

     STRATUM       SAMPLE           G R O S S                         N E T                  DEFECT      TOTAL     SUM OF KPI
                    LOGS   VOL.DC      SE         CV      VOL.DC      SE         CV                      LOGS
 * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

        DF      3P   31    14188       3.00     16.69      13286      3.61     20.09         6.356       238        14442
              SURE    3      184                              39                            78.804         3
             TOTAL         14372       2.96                13325      3.60                   7.284       241

        SALE TOTAL         14372       2.96     16.69      13325      3.60     20.09
```

Figure 6

```
                                          S L O T           3P LOG SCALING   WEST SIDE
SUMMARY FOR SALE                                                                                                        07/26/71
        SALE IDENT       RAFT 61          PAGE    1

     STRATUM       SAMPLE           G R O S S                         N E T                  DEFECT      TOTAL     SUM OF KPI
                    LOGS   VOL.DC      SE         CV      VOL.DC      SE         CV                      LOGS
 * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

        DF      3P   35    35168       1.77     10.49      30026      2.88     17.03        14.621       162        34807
              SURE    0        0                               0                             0.000         0
             TOTAL         35168       1.77                30026      2.88                  14.621       162

        SALE TOTAL         35168       1.77     10.49      30026      2.88     17.03
```

Normally, a single set of random numbers will be used for all strata in a sale, but separate sets could be used for individual strata if more flexibility in sample sizes is essential. However, several sets of numbers are awkward to handle.

SUMMARY

The coefficients of variation (CV) in figures 4, 5, and 6 suggest that 3P log scaling may be very efficient in the sense of providing precise estimates of total volume at small cost. For example, CV's around 20 percent can be expected; with a 20-percent CV, 100 individual sample logs would give an estimate of total timber sale volume which has a 2-percent standard error. Under sample scaling, where the entire truckload of logs is the sampling unit rather than the individual log, CV's of 20 percent or greater are quite common; but a 20-percent CV in this case would require 100 truckloads of logs instead of 100 individual logs for a 2-percent standard error. The cost of scaling 100 truckloads of logs cannot, of course, be compared directly with the cost of scaling 100 individual logs, because the 3P method also requires a guessed volume for every log in the sale. However, in spite of this additional expense, it seems that 3P sample scaling may have a decided advantage.

APPENDIX

Stratum coefficients of variation are standard deviations of the individual sample of R values expressed as a percent of mean R. For "sale total," these CV's are weighted averages over all strata. Thus

$$CV_S = 100 \frac{S}{\bar{R}}$$

where $S = \sqrt{\frac{\Sigma R^2 - (\Sigma R)^2/n}{n - 1}},$

$\bar{R} = \Sigma R/n,$

and CV_S = stratum coefficient of variation;

and

$$CV_T = \frac{100\Sigma n}{\Sigma(\bar{R}n)} \sqrt{\frac{\Sigma S^2 (n-1)}{\Sigma n - k}}$$

where k = number of strata,

CV_T = average coefficient of variation for all strata.

Standard errors in percent ($SE\%$) for volume in the 3P portion of any stratum can be calculated as follows:

$$SE\%_S = CV/\sqrt{n}$$

If there is "sure" volume in a stratum, the standard error of stratum total volume results from multiplying the standard error of the 3P portion by the ratio of 3P volume to stratum total volume. Thus, for gross volume in figure 5:

$$SE\%_{(Total)} = 3.00(14{,}188/14{,}372)$$

$$= 2.96$$

The standard error in percent for total volume for all strata is calculated by this equation:

$$SE\%_{T} = \frac{\sqrt{\Sigma(SE\%V)^2}}{\Sigma V}$$

where V = stratum total volume (summations are for all strata).

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USDA FOREST SERVICE RESEARCH NOTE

PNW-163 August 1971

VOLUME OF LOGGING RESIDUES IN OREGON, WASHINGTON, AND CALIFORNIA-- INITIAL RESULTS FROM A 1969-70 STUDY

by

James O. Howard, *Resource Analyst*

ABSTRACT

A study conducted during 1969-70 in Oregon, Washington, and California indicates that the average net volume of logging residues ranged from 325 to 3,156 cubic feet per acre. The highest volume was on National Forests in the Douglas-fir region, which averaged 2.5 times greater than private lands. The lowest volumes of residue were found in the ponderosa pine region where both private and public lands averaged between 325 and 375 cubic feet per acre. Private lands in California averaged 1,558 cubic feet per acre, while National Forests averaged 1,206 cubic feet per acre. The total net volume of logging residues for all regions was 908 million cubic feet, about 26 percent of the reported 1969 log harvest. In the Douglas-fir region total net volume was 465 million cubic feet, which amounted to 50 percent of the wood consumption by the pulp and board industries in western Oregon and western Washington for 1968.

Keywords: Logging slash, wood waste, waste utilization.

INTRODUCTION

Interest in logging residues has grown rapidly over the last decade. Concern for environmental and esthetic quality has brought about the call for abatement of residues by means other than burning. Yet without burning, logging residues present a continuous and costly problem in protection to the forest manager. Logging residues may also hamper access and limit mobility necessary for management of young-growth stands. In addition, the increasing demand for wood and mounting pressure to remove some forest lands from timber production emphasize logging residues as a potential source of utilizable wood fiber.

What is lacking today are the answers to the vital questions concerning logging residues such as: How much residue material is acceptable on a cutover area from an environmental and esthetic standpoint? At what point does the quantity of logging residues require additional outlays for fire protection purposes? What level of residues is necessary to make it economically feasible to relog an area? What policies or practices help or hinder the abatement of residues during the harvesting operation? A major obstacle to the solution of these problems is the lack of adequate knowledge about the magnitude and characteristics of residues created during harvesting operations.

The Pacific Northwest Forest and Range Experiment Station conducted a study to provide such knowledge. This report summarizes statistics on the volume of residues created during the process of log harvesting operations in 1969. A subsequent report will describe logging residue characteristics. Included in this later report will be classifications of residue by type of material, diameter class, length class, species, concentration, and utilization criteria.

SCOPE AND METHODOLOGY

Information for this study was collected from a sample of 76 cutover units in Oregon, Washington, and California. Some of the data from 14 National Forest tracts sampled in western Washington were shown in a paper by Dell and Ward,[1] which describes logging residues in relation to fire control problems on National Forests of western Oregon and western Washington.

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[1] John D. Dell and Franklin R. Ward. Logging residues on Douglas-fir region clearcuts--weights and volumes. Portland, Oreg., Pac. Northwest Forest & Range Exp. Sta. USDA Forest Serv. Res. Pap. PNW-115, 10 p., illus., 1971.

The population sampled consisted of the total acreage of clearcuts in western Oregon and western Washington and the total acreage of clearcut and selectively logged areas in eastern Oregon, eastern Washington, and California. Within each geographic area, the sample was allocated among owner classes on the basis of the proportion of the total volume cut in each class. Individual sample units were selected by accumulating the total acreage cut within each owner stratum and randomly drawing the sample units from this array of acres, such that all sampling units were drawn with equal probability.

The method used for measuring residue volume was the line intersect method developed in New Zealand in 1964,[2] with modifications developed in Canada.[3] [4] A 30-chain continuous line transect, with a random change in direction every 5 chains, was located within each cutover area sampled.

Logging residues measured in the study included all material left after logging with a minimum diameter of 4 inches outside bark, 4 feet long, and containing at least 10-percent-sound wood fiber. This includes material from trees that were dead at the time of logging. Both gross and net volume estimates were made on each piece of material. The net volume defines the maximum amount of usable wood fiber and does not reflect any product characteristic, such as minimum log length, log grade, sawability, or peelability.

RESIDUE VOLUME PER ACRE

The average cubic-foot volume of residues per acre by geographic area-owner class is displayed in table 1.

The volume of residues by owner group varies considerably within the Douglas-fir region. The average gross volume per acre for the National Forest sample is almost three times greater than the average for private lands and the average net volume about 2.4 times greater. The greater proportion of old-growth timber occurring on the National Forests may account for a large share of the difference, although

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[2] W. G. Warren and P. F. Olsen. A line intersect technique for assessing logging waste. Forest Sci. 10: 267-276, 1964.

[3] C. E. Van Wagner. The line intersect method in forest fuel sampling. Forest Sci. 14: 20-26, 1968.

[4] G. R. Bailey. A simplified method of sampling logging residue. Forest Chron. 46(4): 1-7, 1970.

Table 1.--*Average volume per acre of logging residues by geographic area and owner, 1969*

Geographic area	National Forest			Other public[2]			Private		
	Sample size	Average residue volume		Sample size	Average residue volume		Sample size	Average residue volume	
		Gross	Net[1]		Gross	Net[1]		Gross	Net[1]
		Cubic feet per acre			*Cubic feet per acre*			*Cubic feet per acre*	
Douglas-fir region (western Oregon and western Washington)	22	4,511	3,156 (±543)	8	2,677	2,060 (±432)	24	1,507	1,344 (±231)
Ponderosa pine region (eastern Oregon and eastern Washington)	6	[3]404	[3]325 (±164)	--	--	--	4	423	376 (±91)
California	6	1,499	1,206 (±540)	--	--	--	6	2,093	1,558 (±806)

[1] Figures in parentheses represent the 68-percent confidence interval about the average.

[2] Due to the relatively small volume of timber cut in the "other public" owner group in the ponderosa pine region and California, the statistics were combined with the National Forest stratum.

[3] Includes one sample observation on Indian land in eastern Washington.

economic and policy factors (such as stumpage price and contract specifications) also play an important role.

The low volume of residues in the ponderosa pine region is primarily the result of the lower stand volumes and harvesting methods used. The results shown for California represent both coastal and interior conditions for each owner group, encompassing a range of volumes from 5,400 cubic feet per acre in the coastal redwood zone to 84 cubic feet per acre on a sample in the interior area. A stratification of sample observations into coast range and interior range logging conditions indicated average net volumes of 2,755 and 401 cubic feet per acre, respectively.

A high proportion of logging residue volume has potential as usable wood fiber. In the Douglas-fir region, net volume of logging residue ranged from half to nearly all of the gross volume. As table 1 shows, the average proportion of net volume to gross volume is 70 percent for the National Forest sample, while for private lands the average is almost 90 percent. The same relationship holds in the ponderosa pine region, with the National Forest sample having a lower proportion of usable volume than the private sample. In California, the percentage of usable volume for the private sample is less than for the National Forests. This may be explained by the greater number of National Forest sample observations in the interior region, where the incidence of rot is lower.

TOTAL RESIDUE VOLUME

Table 2 shows the total volume of potentially usable wood fiber--in pieces at least 4 feet long, at least 4 inches in diameter, and with 10 percent or more of the gross volume suitable for pulp chips--left as residue from logging operations in 1969.

Totals for the Douglas-fir region were developed from clearcut acreage estimates furnished by the Washington State Department of Natural Resources, the Oregon State Department of Forestry, and the U.S. Department of Agriculture, Forest Service, Region 6. For the ponderosa pine region of eastern Oregon, eastern Washington, and California, the totals were derived by applying the ratio of the average volume of logging residues per thousand board feet of timber cut from the sampled tracts to the total volume of timber harvested for each owner class. The total volume harvested was supplied by the California Division of Forestry, the Washington State Department of Natural Resources, and the Oregon State Department of Forestry.

The total net residue volume for the three-State area is 908 million cubic feet, equivalent to about 26 percent of the reported 1969 log harvest. Due to such factors as slash burning, relogging, and decay, the figures shown in table 2 represent a larger volume of residues from 1969 logging operations than is actually available today.

Table 2.--*Total net residue volume by geographic area and owner class, 1969*

Geographic area	National Forest	Other public[1]	Private	All owners
	Thousand cubic feet			
Douglas-fir region[2]	142,000	103,000	220,000	465,000
Ponderosa pine region	64,000	--	29,000	93,000
California	134,000	--	216,000	350,000

[1] Due to the relatively small volume of timber cut in the "other public" owner group in the ponderosa pine region and California, the statistics were combined with the National Forest stratum.

[2] Volume from clearcut operations only. Estimated clearcut acreages for the Douglas-fir region: National Forest, 45,000 acres; other public, 50,000 acres; private, 163,600 acres.

Preliminary analysis indicates that in the Douglas-fir region approximately 59 percent of the total net residue volume is in pieces 12 feet or longer, with 50 percent or more of the gross volume suitable for pulp chips. This physical standard nearly meets the definition of a utility log, the minimum log grade currently used.

The total net volume of logging residue generated annually in the Douglas-fir region, most of which is not now economically available, represents a sizable potential source of wood fiber. In 1969, the total net volume of logging residues in the Douglas-fir region was 465 million cubic feet (table 2), equivalent to just over 50 percent of the total raw material consumption by the pulp, paper, and board industries of the region. As economic and technological changes occur, logging residues may present a substantial base for increases in paper and board production, with no additional drain on the timber resource of the region.

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USDA FOREST SERVICE RESEARCH NOTE

PNW-164 September 1971

VENEER YIELD BY LOG GRADE AND SIZE FROM BLACK HILLS PONDEROSA PINE

by

Richard O. Woodfin, Jr., *Forest Products Technologist*

and

Paul H. Lane, *Principal Wood Technologist*

ABSTRACT

Veneer grade recovery by log diameter class and log grade for ponderosa pine is presented from 236 Black Hills ponderosa pine logs. Log diameters ranged from 7 to 18 inches. Average veneer recovery was 3 percent in grades A and B, 44 percent in grade C, and 53 percent in grade D.

Keywords: Veneer logs, ponderosa pine.

INTRODUCTION

To help determine potential veneer yields from South Dakota Black Hills ponderosa pine (*Pinus ponderosa* Laws.), a recovery study was conducted jointly by the marketing research project of the Rocky Mountain Forest and Range Experiment Station and the timber quality research project of the Pacific Northwest Forest and Range Experiment Station. This study contributed to an analysis by the Rocky Mountain Station of the feasibility of producing plywood from ponderosa pine in the Black Hills. It also has provided information that is useful in relating veneer recovery to ponderosa pine log grades and sizes.

This report summarizes the veneer grade yield information from the study according to ponderosa pine log grade[1] and log diameter. The procedures and other results of the study related to plywood production are described in considerably more detail in a research paper by the Rocky Mountain Station.[2]

The veneer yield data from the study are based on 144 trees selected from eight areas considered representative of the commercial timber available in the Black Hills. The sample trees were bucked into 236 logs and trucked to the Montezuma Plywood plant at Dolores, Colorado, for peeling under this plant's normal commercial production conditions. The distribution of log lengths by the improved ponderosa pine log grades is shown in table 1.

Table 1.--*Distribution of study logs by length*

Log grade	Log length in feet					Percent
	8	17	26	34	Total	
	Number of logs					
1	--	--	--	3	3	1.3
2	--	3	9	21	33	14.0
3	--	9	21	21	51	21.6
4	--	--	1	--	1	.4
5	9	43	64	32	148	62.7
Total	9	55	95	77	236	100.0

---

[1] *The log grades referred to in this report are from Edward M. Gaines, "Improved system for grading ponderosa pine and sugar pine saw logs in trees," USDA Forest Serv. Pac. Southwest Forest & Range Exp. Sta. Tech. Pap. 75, 21 p., 1962.*

[2] *Vern P. Yerkes and Richard O. Woodfin, Jr. Veneer recovery from selected sample of Black Hills ponderosa pine. Rocky Mt. Forest & Range Exp. Sta. USDA Forest Serv. Res. Pap. 82, illus.*

The logs were cut into 8-foot peeler blocks, debarked, steamed, and peeled into one-tenth-inch veneer. The dry, untrimmed veneer was graded under the supervision of the American Plywood Association. All veneer was sorted and tallied on a rough, dry untrimmed basis into seven grades--A, A patch (Ap), B, B patch (Bp), C, D, and E. The A, B, C, and D grades are as described in the Plywood Product Standard Handbook.[3] Ap veneer is A grade that permits up to 14 patchable defects in a 4- by 8-foot sheet. Bp veneer is B grade that permits up to 20 patchable defects in a 4- by 8-foot sheet. E veneer is grade D with admissible rot.

VENEER RECOVERY

The veneer yield from the 236 study logs is summarized in figure 1 and tables 2 through 8. The sample included only one grade 4 log which

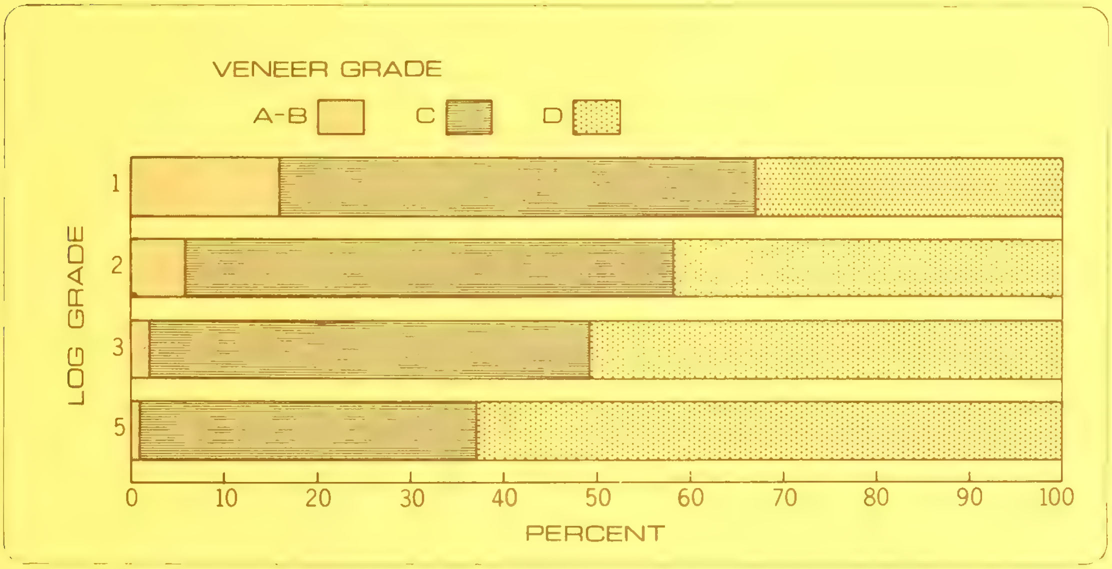

Figure 1.--Distribution of veneer grade recovery percentages by log grades. Only one grade 4 log was sampled, and it is not included.

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[3] *Reprinted from "U.S. Product Standard PS 1-66 for Softwood Plywood--Construction and Industrial." Prepared by American Plywood Association, Tacoma, Wash., 1970.*

Table 2.--*The distribution of log volume*[1] *and veneer recovery by log grade*

Log grade	Number of logs	Gross scale	Net scale	Percent sound	Veneer volume, 3/8-inch basis	Recovery ratio[2]
		---*Board feet*---			*Square feet*	
1	3	750	740	99	2,558	3.46
2	33	7,090	6,790	96	22,024	3.24
3	51	7,830	7,490	96	23,321	3.11
4	1	130	130	100	362	2.78
5	148	11,840	11,480	97	32,312	2.81
Total	236	27,640	26,630	96	80,577	3.03

[1] Log volume was measured by Scribner Decimal C log rule, U.S. Forest Service scaling handbook rules, 20-foot maximum scaling length.

[2] Based on rough, dry untrimmed veneer volume expressed as a ratio of net log scale.

Table 3.--*Log grade 1—dry untrimmed veneer grade recovery percentages by diameter*

Diameter (inches)	Number of logs	Veneer volume, 3/8-inch basis	Veneer grade							Total
			A	Ap	B	Bp	C	D	E	
		Square feet	---------*Percent*---------							
12	1	660	--	--	7.1	4.4	56.1	16.3	16.1	100.0
13	--	--	--	--	--	--	--	--	--	--
14	2	1,898	1.5	--	9.5	6.5	49.7	23.6	9.2	100.0
Total	3	2,558	1.1	--	8.9	6.0	51.3	21.8	10.9	100.0

Table 4.--*Log grade 2—dry untrimmed veneer grade recovery percentages by diameter*

Diameter (inches)	Number of logs	Veneer volume, 3/8-inch basis	Veneer grade							Total
			A	Ap	B	Bp	C	D	E	
		Square feet	--------------------------------------*Percent*--------------------------------------							
7	1	172	--	--	--	--	52.9	47.1	--	100.0
8	2	137	--	--	--	--	67.2	32.8	--	100.0
9	2	645	--	--	--	--	18.9	81.1	--	100.0
10	6	1,739	0.6	0.6	2.2	2.8	61.0	25.1	7.7	100.0
11	3	1,536	--	--	3.5	2.5	38.1	40.1	15.8	100.0
12	--	--	--	--	--	--	--	--	--	--
13	5	3,877	--	--	3.7	5.0	51.3	33.0	7.0	100.0
14	6	5,315	1.7	--	4.4	2.9	53.5	31.1	6.4	100.0
15	4	3,821	--	--	1.8	2.1	50.5	39.3	6.3	100.0
16	3	3,268	--	--	.4	5.4	57.2	33.8	3.2	100.0
17	1	1,514	--	--	.6	0.7	62.5	27.2	9.0	100.0
Total	33	22,024	0.4	(1/)	2.5	3.2	52.3	34.9	6.7	100.0

1/ Value less than 0.05 percent.

Table 5.--*Log grade 3—dry untrimmed veneer grade recovery percentages by diameter*

Diameter (inches)	Number of logs	Veneer volume, 3/8-inch basis	Veneer grade							Total
			A	Ap	B	Bp	C	D	E	
		Square feet	--------------------------------------*Percent*--------------------------------------							
7	2	155	--	--	--	3.2	25.8	71.0	--	100.0
8	8	778	--	--	--	1.3	69.2	21.5	8.0	100.0
9	5	949	--	--	2.0	1.1	68.5	26.1	2.3	100.0
10	3	796	--	--	.6	--	75.9	13.8	9.7	100.0
11	7	2,793	--	--	1.7	5.5	52.0	34.7	6.1	100.0
12	10	5,357	--	0.5	.2	2.0	50.3	43.8	3.2	100.0
13	9	6,462	--	--	--	.6	46.4	47.8	5.2	100.0
14	3	1,536	--	--	.3	--	26.6	73.1	--	100.0
15	2	1,786	--	--	--	--	38.2	61.2	.6	100.0
16	--	--	--	--	--	--	--	--	--	--
17	1	1,305	--	--	--	--	10.3	89.5	.2	100.0
18	1	1,404	--	--	.6	1.0	56.1	42.3	--	100.0
Total	51	23,321	--	.1	.4	1.4	47.1	47.3	3.7	100.0

Table 6.--*Log grade 5—dry untrimmed veneer grade recovery percentages by diameter*

Diameter (inches)	Number of logs	Veneer volume, 3/8-inch basis	Veneer grade							Total
			A	Ap	B	Bp	C	D	E	
		Square feet	-----------------	-----	-----	*Percent*	-----	-----	-----	-----------------
7	32	2,704	--	--	--	--	43.9	55.2	0.9	100.0
8	50	6,850	--	--	--	0.1	30.1	68.9	.9	100.0
9	26	5,725	--	--	0.3	.4	34.1	64.9	.3	100.0
10	13	3,854	--	--	--	.3	41.7	55.3	2.7	100.0
11	9	2,644	--	--	--	--	46.1	53.9	--	100.0
12	5	2,287	--	--	--	1.7	37.6	57.2	3.5	100.0
13	6	2,493	--	--	.1	--	23.1	76.8	--	100.0
14	5	3,706	--	--	--	.3	40.4	58.2	1.1	100.0
15	2	2,049	--	--	.2	3.0	35.0	61.6	.2	100.0
Total	148	32,312	--	--	.1	.5	36.1	62.3	1.0	100.0

Table 7.--*All log grades combined—dry untrimmed veneer grade recovery percentages by diameter*

Diameter (inches)	Number of logs	Veneer volume, 3/8-inch basis	Veneer grade							Total
			A	Ap	B	Bp	C	D	E	
		Square feet	-----------------	-----	-----	*Percent*	-----	-----	-----	-----------------
7	35	3,031	--	--	--	0.2	43.5	55.5	0.8	100.0
8	60	7,765	--	--	--	.2	34.7	63.5	1.6	100.0
9	33	7,319	--	--	0.5	.5	37.2	61.2	.6	100.0
10	23	6,751	0.1	0.1	.6	.9	51.5	42.1	4.7	100.0
11	19	6,973	--	--	1.4	2.8	46.7	43.2	5.9	100.0
12	16	8,304	--	.3	.7	2.1	47.2	45.4	4.3	100.0
13	20	12,832	--	--	1.1	1.8	43.4	48.9	4.8	100.0
14	16	12,455	.9	--	3.4	2.3	45.7	43.3	4.4	100.0
15	8	7,656	--	--	.9	1.9	43.5	50.4	3.3	100.0
16	3	3,268	--	--	.4	5.4	57.2	33.8	3.2	100.0
17	2	2,819	--	--	.3	.4	38.3	56.1	4.9	100.0
18	1	1,404	--	--	.6	1.0	56.1	42.3	--	100.0
Total	236	80,577	0.2	(1/)	1.1	1.7	44.3	49.1	3.6	100.0

[1/] Less than 0.05 percent.

Table 8.--*Percentage of dry untrimmed veneer recovered by width and length of veneer sheets*[1] *for each log grade*

Log grade	Veneer volume, 3/8-inch basis	8-foot length			4-foot length
		Full width	Half width	Random width	Random width
	Square feet	*Percent*			
1	2,558	61.8	8.0	23.1	7.1
2	22,024	58.5	6.4	27.4	7.7
3	23,321	52.8	7.0	31.5	8.7
4	362	52.8	5.2	29.8	12.2
5	32,312	47.6	7.0	33.7	11.7
Total	80,577	52.5	6.9	31.0	9.6

[1] Average sizes of the dry untrimmed veneer were 101 inches for 8-foot lengths, 51 inches for 4-foot lengths, 51 inches for full-width sheets, and 25 inches for half-width sheets.

yielded 362 square feet of veneer on a 3/8-inch basis. Fifty-seven percent of this volume was grade C veneer and 43 percent, grade D. The specification for a grade 4 log describes a log with numerous small knots that is expected to yield a large portion of high grade common lumber. This log is not usually found in Black Hills ponderosa pine.

The yield of C and better grades of veneer decreased progressively from 67 percent for log grade 1 to 37 percent for log grade 5 as shown in figure 1. Conversely, there was about 10-percent increase in the amount of D veneer for each log grade, starting with 33 percent for log grade 1.

The average veneer grade yield for all log grades was about 3 percent B, 44 percent C, and 53 percent grade D (table 7). About 50 percent of both grades C and D veneer volumes were produced as full sheets of veneer (nominal 4 by 8 feet). About 40 percent of the volume was random width strips and the rest was half sheets. Since grades C and D veneer account for about 97 percent of the total veneer volume produced in this sample, it is expected that a sheathing type C-D plywood panel could be produced from Black Hills pine.

The suitability for plywood production of the veneer grade and size distribution recovered in this sample is discussed in the Rocky Mountain Forest and Range Experiment Station paper by Yerkes and Woodfin (see footnote 2).

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GROWTH OF YOUNG EVEN-AGED WESTERN LARCH STANDS AFTER THINNING IN EASTERN OREGON

by

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ABSTRACT

The 5-year growth response of a 33-year-old pure even-aged western larch stand thinned to a wide range of stocking levels was measured in eastern Oregon. Both basal area and volume growth increased as stand density increased, with volume growth increasing from a low of 64 cubic feet per acre annually at the lowest density to 133 cubic feet at the highest density.

Despite the large reduction in volume increment at the lowest density, there was a substantial transfer of growth from many slowly growing trees to a lesser number of faster growing ones. Ninety-six trees at the lowest density produced approximately half as much wood as 745 trees at the highest density. Diameter growth at the lowest density level was sharply increased over that at the higher levels.

Keywords: Stand density, thinning (trees), forest measurement, stand increment estimates, western larch, *Larix occidentalis*.

Western larch (*Larix occidentalis* Nutt.) is an important species in the forests of the Blue Mountains of northeastern Oregon growing in both pure and mixed stands. According to a 1963 forest survey, there are about 400,000 acres on which larch is the predominant species in eastern Oregon, and about 38,000 acres are occupied by pole-sized stands.[1]

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[1] Donald R. Gedney. Toward complete use of eastern Oregon's forest resources. Portland, Oreg., Pac. Northwest Forest & Range Exp. Sta. USDA Forest Serv. Resour. Bull. PNW-3, 71 p., illus., 1963.

Although utilization of this species is increasing, there is little growth and yield information available from managed stands to aid the forest manager in thinning operations in pole-sized stands.

In 1966, a study designed to provide basic information on the response of pure even-aged larch stands to a wide range of stocking levels was begun in northeastern Oregon. This interim report covers the first 5-year period of the study.

STUDY AREA AND METHODS

The study is located on the Union District of the Wallowa-Whitman National Forest about 15 miles southeast of Union, Oregon, at an elevation of about 4,000 feet. The stand was 33 years old when first thinned in 1966 and has a site index of about 80 feet at age 50.[2] The soil is classified as a Tolo silt loam, which is a well-drained regosol developed from dacite pumicite originating from the eruption of Mount Mazama (Crater Lake) 6,500 years ago. It is underlain at a depth of about 3 feet by a buried soil developed from basalt.

Many shrubs and herbs typical of the *Abies grandis/Calamagrostis rubescens* habitat type such as pinegrass (*Calamagrostis rubescens* Buckl.), heartleaf arnica (*Arnica cordifolia* Hook.), white hawkweed (*Hieracium albiflorum* Hook.), and *Ribes* spp. are found on the study area.[3]

Ten 0.4-acre plots were located in the study area and five levels of stocking were created by thinning. Each level was replicated two times. The density measure used in this study is bole area, which is the cambial area of the main stem. For those not familiar with bole area, corresponding densities in terms of basal area are also given. The five bole area levels used in this study are 5,000, 10,000, 15,000, 20,000, and 25,000 square feet per acre. Plots will be rethinned according to the same density levels every 10 years. On two of the 10 plots (one at the 25,000- and one at the 20,000-square-foot level), about 40 percent of the bole area and basal area left after thinning was lodgepole pine (*Pinus contorta* Dougl.).

In general, plots were thinned from below, the objective being to leave the required number of the best trees as evenly spaced as possible over the plot (fig. 1). None of the slash from the thinning was removed from the plots.

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[2] Site index based on curves in "Ecology and Management of Western Larch," by Arthur L. Roe, Raymond C. Shearer, and Wyman C. Schmidt, USDA Tech. Bull., in preparation.

[3] For a discussion of the habitat types in the *Abies grandis* zone in the Blue Mountains, see "Vegetation of Oregon and Washington," p. 129-134, by Jerry F. Franklin and C. T. Dyrness, USDA Forest Serv. Res. Pap. PNW-80, Pac. Northwest Forest & Range Exp. Sta., Portland, Oreg., 1969.

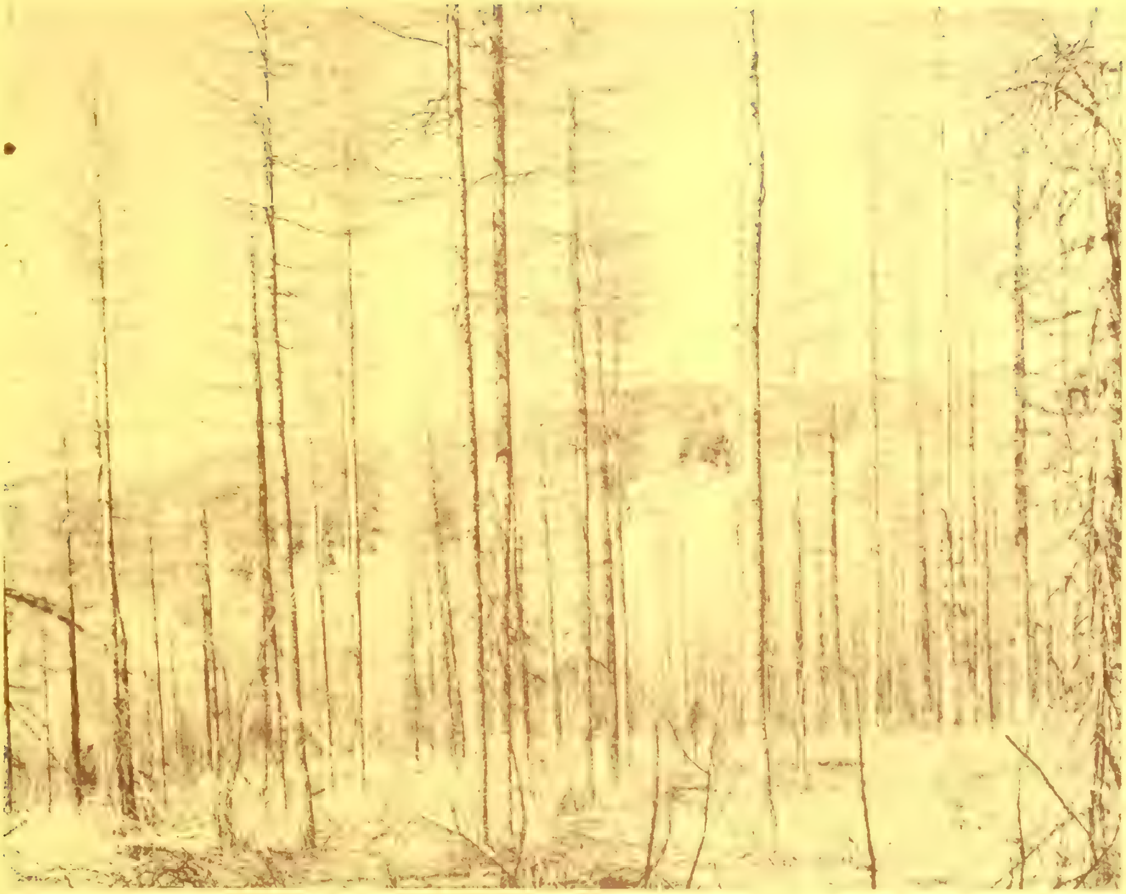

Figure 1.—One of the 10,000-square-foot bole area density plots after thinning, with an average spacing of 14 feet. Basal area is about 50 square feet per acre.

All plots were well stocked before treatment, each containing at least 25,000 square feet of bole area per acre (table 1). Trees were spaced about 5.5 to 7 feet apart and average diameter was about 4.5 inches.

Diameters of all plot trees were measured to the nearest one-tenth inch in 1966 and 1970. On each plot, about 15 trees covering the range of diameters present were measured with an optical dendrometer in 1966 and 1970 for the purpose of calculating an equation expressing volume and bole area of the entire stem as a function of diameter for each plot. These equations were used to compute plot volumes and bole areas. A new equation was calculated for each period. Height growth was measured by dendrometer on those trees chosen for volume equation measurements. Analysis of variance and Duncan's multiple range test were used to test the significance of treatment effect. The word "significant" when applied to treatment effects indicates statistical significance at the 5-percent level.

Table 1.--*Stand characteristics per acre of western larch before and after 1966 thinning and 5 years later*

Density level	Bole area	Basal area	Number of stems	Average spacing	Average diameter[1]	Average height[2]	Volume[3]		
							Total	Merchantable including ingrowth	
	Square feet			*Feet*	*Inches*	*Feet*	*Cubic feet*		*Board feet*
Before initial (1966) thinning:									
1	25,800	118.6	924	6.9	4.9	48.4	1,995	1,180	48
2	31,125	132.7	1,161	6.1	4.6	46.2	2,287	1,088	--
3	34,180	139.2	1,406	5.6	4.3	46.5	2,367	885	193
4	32,880	143.7	1,377	5.6	4.4	42.9	2,322	1,125	--
5	32,700	135.6	1,459	5.5	4.1	42.0	2,200	964	--
After thinning:									
1	4,708	26.0	96	21.3	7.0	48.4	474	389	48
2	9,524	49.6	215	14.2	6.5	46.2	902	648	--
3	14,242	70.9	355	11.1	6.1	46.5	1,272	782	193
4	19,313	96.4	546	8.9	5.7	42.9	1,616	1,039	--
5	24,203	109.8	745	7.6	5.2	42.0	1,847	961	--
1971:									
1	6,374	40.3	96	21.3	8.8	55.4	794	678	948
2	12,069	68.2	215	14.2	7.6	51.7	1,333	1,060	294
3	17,797	93.4	354	11.1	7.0	53.3	1,780	1,261	532
4	23,810	120.5	539	9.0	6.4	49.1	2,250	1,562	345
5	29,121	134.3	740	7.7	5.8	48.0	2,510	1,435	102
Thinning yield:									
1	--	--	828	--	--	--	1,521	791	--
2	--	--	946	--	--	--	1,385	440	--
3	--	--	1,051	--	--	--	1,095	103	--
4	--	--	831	--	--	--	706	86	--
5	--	--	714	--	--	--	353	3	--

[1] Diameter of the tree of average basal area.

[2] Average height of trees measured with dendrometer (about 15 per plot).

[3] Total cubic-foot volume--entire stem, inside bark, all trees.

Merchantable cubic-foot volume--trees 5.0-inch d.b.h. and larger to a 4-inch top d.i.b.

Board-foot volume--International 1/4-inch scale, trees 10.0-inch d.b.h. and larger to a 6-inch top d.i.b.

RESULTS

Individual Tree Growth

Diameter growth.--Trees grew fastest in diameter on the plots with the lightest stocking (fig. 2). Each reduction of 5,000 square feet of bole area resulted in a significant increase in diameter growth, and the average growth of all trees at the lowest density (0.36 inch per year) was more than three times the growth at the highest density (0.11 inch per year).[4]

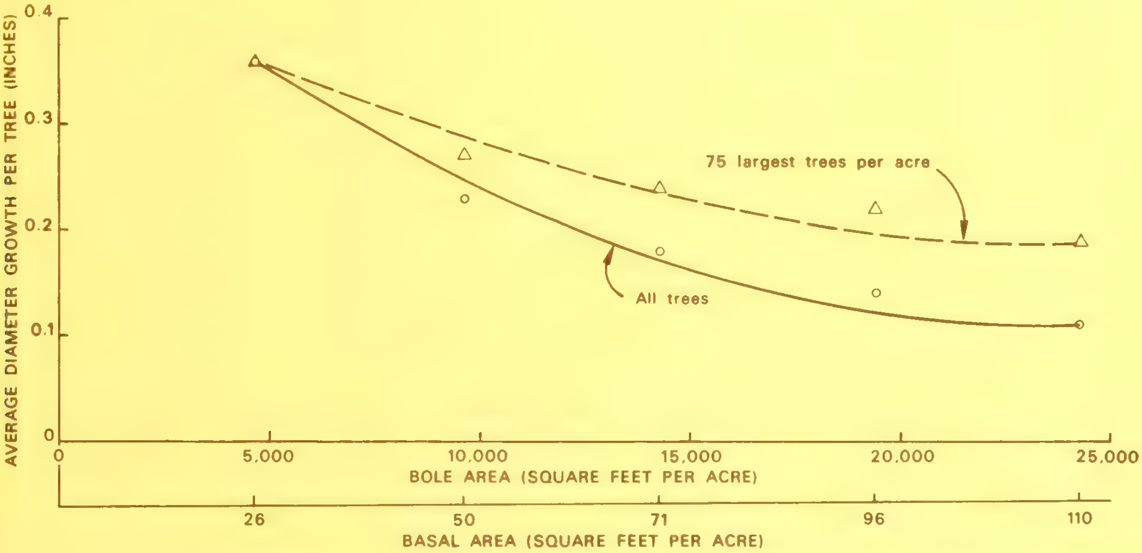

Figure 2.—Relation between density after thinning and periodic annual diameter growth.

Comparison of diameter growth of the 75 largest diameter trees per acre with growth of all trees shows the largest trees in each density level grew the fastest (fig. 2). At the highest density, diameter growth of the 75 largest trees per acre (0.19 inch) is almost twice as much as that of all trees (0.11 inch). This difference becomes more pronounced as bole area increases because of more smaller, slower growing trees in the denser plots. Also, diameter growth of the largest trees in a stand is affected by increasing stand density in the same manner as is growth of all trees; growth dropped from 0.36 inch at the low bole area level to 0.19 inch at the high density because of the greater competition of additional trees. In other words, even though the largest trees in the stand are the most vigorous and occupy the most favorable position, they are not independent of stand density with respect to diameter growth.

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[4] Ratios of wood to bark were not significantly different among any of the treatments at either measurement nor was there any significant change in ratios between the two measurements. Therefore, differences in bark growth are not involved in the diameter growth data.

There was little difference in average diameter growth between larch and lodgepole. At the highest density level, larch grew 0.114 inch per year and lodgepole, 0.118 inch. At the second highest level, diameter growth of larch was slightly greater than that of lodgepole (0.142 vs. 0.128 inch per year). These were the only two levels containing lodgepole pine.

Height growth.--There was no significant effect of stand density on total height growth, nor was there any indication that total height growth was correlated with density. Trees grew an average of 5.6 to 7.0 feet in total height (table 2), and growth of individual trees ranged from 0.6 foot to 11.7 feet during the 5-year period. As might be expected, there was a consistent increase in total height growth with tree diameter at all density levels except the two largest diameter classes at the lowest density. This is the same relationship found for diameter growth and simply means that in a young even-aged stand, the largest trees grow the fastest--in both diameter and height--because they are the most vigorous trees in the best competitive position.

When considering merchantable height growth to a 4-inch top diameter inside bark, density was found to have a significant effect. This was due entirely to the significant increase in merchantable height of trees in the lowest density plots compared with the other levels. The greatest increase in merchantable height (11 feet) occurred in the 5- and 6-inch diameter classes at the lowest density, almost twice as much as in the same diameter classes at the highest density (table 2). This greater merchantable height growth at the lower density is not due to greater total height growth (since it varies little by density) but to increased diameter growth along the entire length of the bole of trees in the low-density plots. For example, the average 5-year diameter growth at a height of 30 feet of 5- and 6-inch trees at the lowest density was 1.3 inches, but at the highest density it was only 0.6 inch.

In the two plots containing both larch and lodgepole, there was almost no difference in total height growth between the two species. On one plot, larch height growth averaged 5.9 feet and lodgepole, 5.6 feet; on the other plot, larch grew 5.6 feet and lodgepole, 5.7 feet during the 5 years.

Stand Growth

Basal-area growth.--Gross basal area increment increased from 2.86 to 5.07 square feet per acre per year as stocking increased from the lowest to highest level (fig. 3). The greatest increase in growth occurred as stand density rose from 5,000 to 15,000 square feet of bole area (or from 26 to 71 square feet of basal area). At densities greater than 15,000 square feet of bole area, growth was relatively uniform.

Table 2.--*Average total and merchantable height growth from 1966 to 1971 by initial diameter class and density level*

Density level and 1966 diameter class	5-year height growth	
	Total	Merchantable[1]
	Feet	
1 (low):		
5-6 inches	6.4	11
7-8 inches	7.3	9
9-10 inches	7.1	8
Average	6.9	9
2:		
3-4 inches	4.4	--
5-6 inches	5.4	9
7-8 inches	6.1	7
9-10 inches	6.5	6
Average	5.6	7
3:		
3-4 inches	5.6	--
5-6 inches	6.5	7
7-8 inches	7.2	6
9-10 inches	8.7	7
Average	7.0	7
4:		
3-4 inches	5.8	--
5-6 inches	6.2	7
7-8 inches	6.3	6
9-10 inches	7.8	6
Average	6.5	6
5 (high):		
3-4 inches	4.6	--
5-6 inches	5.7	6
7-8 inches	6.6	7
9-10 inches	7.6	7
Average	6.1	7

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[1] Merchantable height to 4-inch top d.i.b.

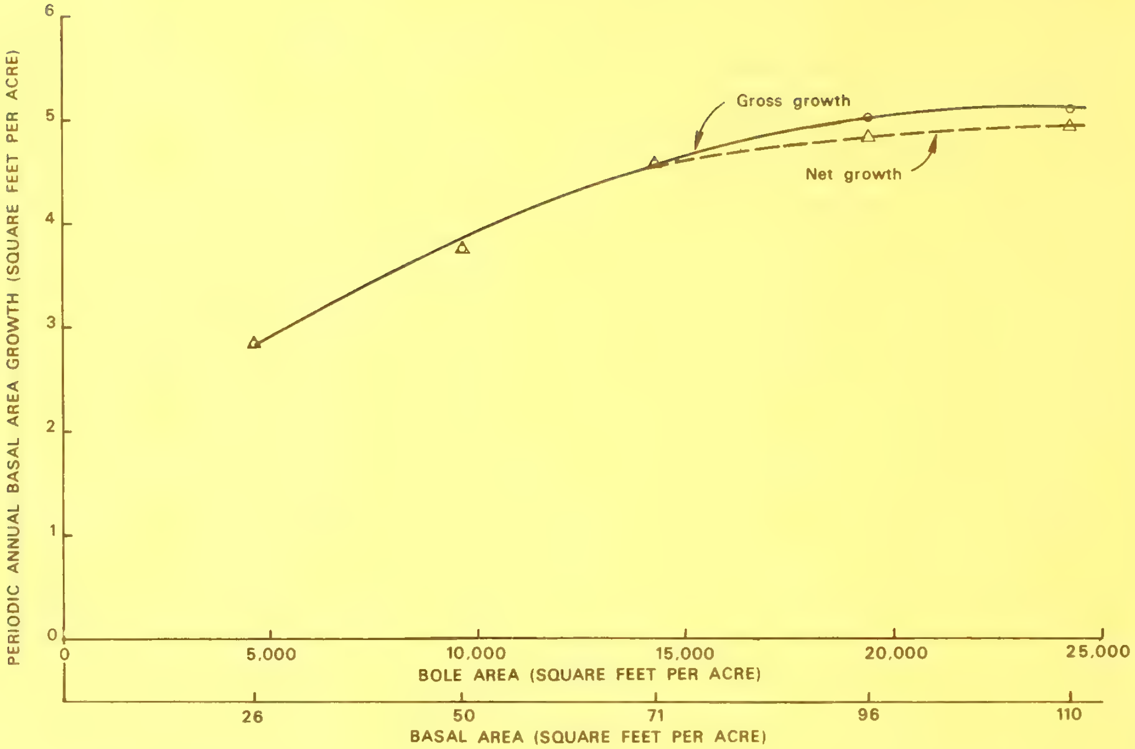

Figure 3.–Relation between density after thinning and periodic annual basal area growth.

Basal area accumulated most rapidly per unit of initial basal area at the lowest density level (increasing to 1.6 times its initial amount), where diameter growth was the greatest. At the highest stocking level, the increase was 1.2 times the initial base. Thus, even though basal area accumulated more rapidly per unit of initial basal area at the lowest level, the 5-year increment was greatest at the highest density because of the larger base of growing stock.

Because of the small amount of mortality on these plots (only 12 of 1,567 trees died), net basal area increment is essentially the same as gross growth except for a slight decrease at the higher densities where the mortality occurred.

Volume growth.--Total gross volume increment was affected by stand density in the same manner as was basal area increment, volume growth increasing from 64 cubic feet per acre per year at the lowest stocking level to 136 cubic feet per acre per year at the highest density (fig. 4). Mortality was only 3 cubic feet per acre per year (table 3) in the high density stand, so total net increment was only slightly less than gross growth as basal area stocking became greater than 70 square feet per acre. Any increase of 10,000 square feet of bole area resulted in a

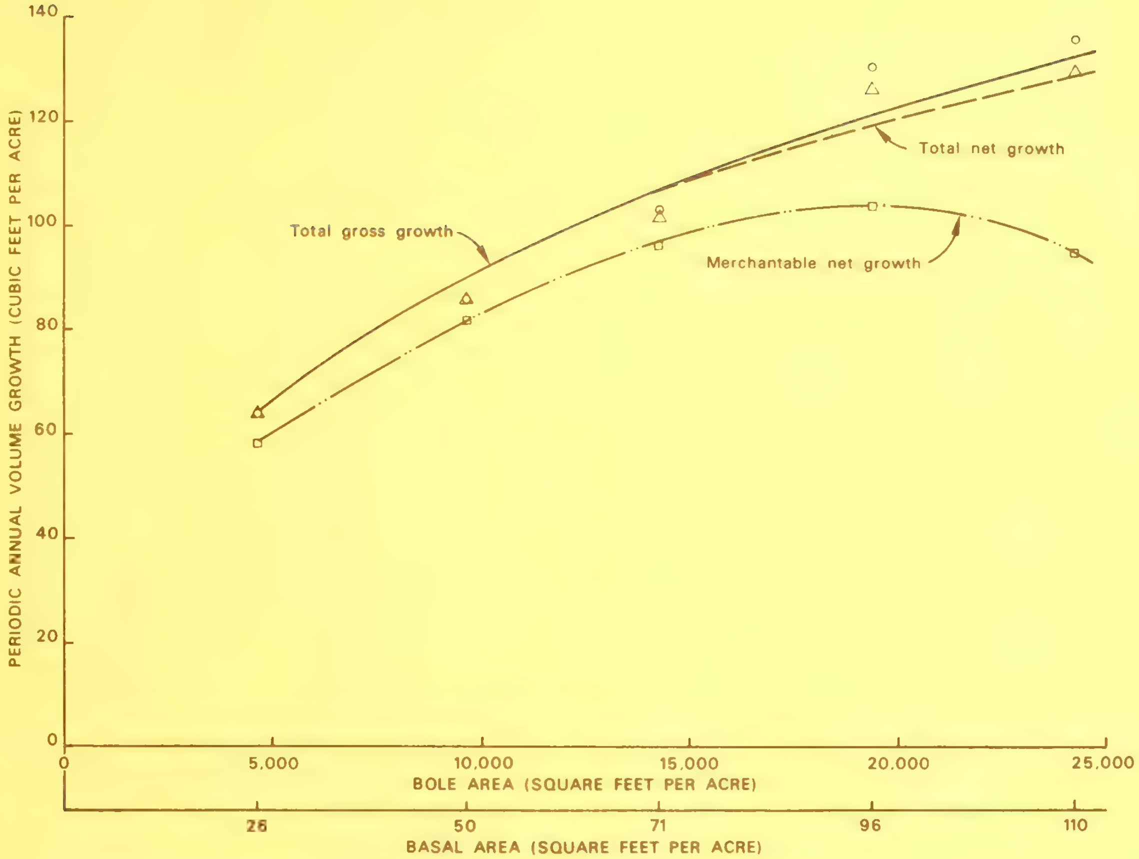

Figure 4.–Relation between density after thinning and periodic annual volume growth.

significant rise in total volume increment. Increases from 5,000 to 10,000 and from 15,000 to 20,000 square feet of bole area also resulted in significant increases in volume growth.

When merchantable growth in trees 5.0-inch d.b.h. and larger to a 4-inch top is considered, the results are somewhat different. Here, each density increase resulted in a significant increase in merchantable volume increment until bole area reached 15,000 square feet (fig. 4). The next increase in density caused a continued rise in volume growth, followed by a reduction in growth at the highest stocking level. Therefore, smaller trees under 5-inch d.b.h. account for a considerable amount of the total volume growth at the highest density.

In terms of total volume growth, figure 4 illustrates that the full productive capacity of the site has not been utilized since growth continued to increase at each density level. However, full site utilization would probably be reached at a stand density not much greater than 110 square feet of basal area since the growth curve showed a tendency to level off at the upper stocking levels. Although maximum total wood

Table 3.--*Periodic annual growth and mortality per acre of western larch stands after initial thinning at age 33*

Density level	All trees											75 largest trees	
	Residual density		Diameter growth	Basal area growth			Total volume growth			Merchantable net volume growth including ingrowth		Diameter growth	Gross total volume growth
	Bole area	Basal area		Net growth	Mortality	Gross growth	Net growth	Mortality	Gross growth				
	---*Square feet*---		*Inches*	-------*Square feet*-------			--------*Cubic feet*-------			*Cubic feet*	*Board feet*	*Inches*	*Cubic feet*
1	4,700	26.0	0.36	2.86	--	2.86	64	--	64	58	180	0.36	54
2	9,500	50.0	.23	3.72	--	3.72	86	--	86	82	59	.27	40
3	14,250	71.0	.18	4.50	.03	4.53	102	1	103	96	68	.24	31
4	19,300	96.0	.14	4.82	.19	5.01	127	4	131	104	69	.22	30
5	24,200	110.0	.11	4.90	.17	5.07	133	3	136	95	22	.19	28

production is attained at the highest stocking level, the volume is, of course, distributed among a large number of small trees, many of which are not usable. In contrast, at the lower basal area levels there is some reduction in total production, but the growth is on fewer and larger trees. Thus individual trees grow faster in both diameter and volume, permitting shorter rotations. This is shown in table 3 where the volume growth of the 75 largest trees per acre increased from 28 to 54 cubic feet per acre per year as stocking decreased.

Board-foot growth in these young pole stands means little since most of the trees are below merchantability limits. It is shown only as a reference for future growth measurements. On most plots, all of the board-foot growth was ingrowth.

DISCUSSION

The diameter and volume growth responses found in this study are typical of those found in most thinning studies of young, even-aged stands. Generally, in such studies, diameter growth slows markedly as density increases and volume increment rises with increasing stocking or remains relatively constant over a wide range of stand densities. Height growth response is more variable, in some cases being rather insensitive to changes in density, as in this study, and in others showing increased growth as a result of thinning, especially if stands had been extremely overstocked.

Decisions concerning thinning intensity depend upon many factors such as number of years between thinnings, average stand diameter, rotation age, present and future markets for small trees, and multiple-use considerations involving water yield, forage, wildlife habitat, or esthetic values. Obviously, firm recommendations for thinning intensity in larch stands in eastern Oregon cannot be made from a base of only 5 years of data from a single study. However, for young stands on good sites such as these, some general observations seem appropriate. If markets for small trees are available, if frequent thinnings are possible, and if the management objective is to maximize wood production, then a high residual stand density is suggested in order to more fully utilize the productive potential of the site. On the other hand, if no pulpwood market exists, if thinning cycles are long, and if the land is managed under multiple-use objectives, then a heavier initial thinning is indicated.

Using the results of this study and certain necessary assumptions, an estimate can be made of the stocking to leave after the first thinning where there is no pulpwood market. The following assumptions will apply:

1. The initial thinning will be a precommercial thinning designed to achieve a rapid enough diameter growth rate on the residual trees so that a commercial thinning may be made at the next entry.

2. The second (commercial) thinning will be made 20 years after the initial thinning, and at this time all trees removed must be merchantable (at least 10.0-inch d.b.h.).

3. Basal area increment will continue at about the present rate during the 20-year period since the increased rate from rising stand density will be offset by a falling rate expected with greater age.

4. Little mortality will occur during the 20 years.

Under these conditions, the average stand diameter 20 years after the initial thinning can be estimated by adding the basal area growth during the period to the basal area present after thinning and computing average diameter as the diameter of the tree of mean basal area. Table 4 shows the estimated change in average diameter of the three lowest density levels. In order to have all trees reach a diameter of 10 inches 20 years after the first thinning, the average stand diameter would have to be about 12 inches. In the example given, this would require leaving about 120 trees per acre at an average spacing of about 19 feet.

It should be emphasized that this decision is based on the facts and assumptions used in this example. Some foresters will very likely use different assumptions. However, as it is important to recognize that trees should be merchantable at the time of the next thinning, the spacing selected for the initial thinning should take this requirement into account.

Table 4.--*Estimated change in basal area and average diameter per acre of larch stands 20 years after thinning to three density levels*

Density level	Number of stems		Annual basal area growth	Basal area		Average diameter	
	1966	1986		1966	1986	1966	1986
			--------Square	*feet-------*		*Inches*	
1	96	96	2.8	26	82	7.0	12.5
2	215	215	3.7	50	124	6.5	10.3
3	355	355	4.4	71	159	6.1	9.1

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· USDA FOREST SERVICE RESEARCH NOTE

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INHERITANCE OF STOCKINESS IN PONDEROSA PINE FAMILIES

by

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ABSTRACT

Diameters at average seedling height of 31.25 centimeters among 41 families were 22 percent greater from stocky parents than from slender parents, though average heights were not significantly different. Low relationship between stockiness and height suggests that selection for tall stocky types is feasible. About 19 percent of the deviation of volumes of 3-year-old progeny from a common regression on height was attributable to parental type.

Keywords: Tree genetics, ponderosa pine, tree diameter measurement.

INTRODUCTION

Inheritance of stockiness or slenderness, so commonly observed in animals and plants, has also been observed in trees, particularly ponderosa pine. The trait has received little attention from forest geneticists but deserves more.

Weidman[1] observed striking slenderness differences among 20 ponderosa pine races in an Idaho study. Squillace and Silen[2] defined taper as average height of a race for a 6-inch diameter tree and estimated broad sense heritability of taper differences at 0.41 among 10 races of ponderosa pine studied in Oregon and Washington. Racial differences, however, are not as useful to the tree breeder as would be the inherent differences in stockiness transmitted by an individual parent to its offspring. This study explores the inheritance of a similar trait, average diameter at a given height, in 3-year-old families from selected phenotypically stocky and slender parent trees.

Height-adjusted diameter is more than just another expression of diameter. Figure 1 illustrates two seedling families grown at the same spacing where there is a difference in diameter at each height. Such genetic control

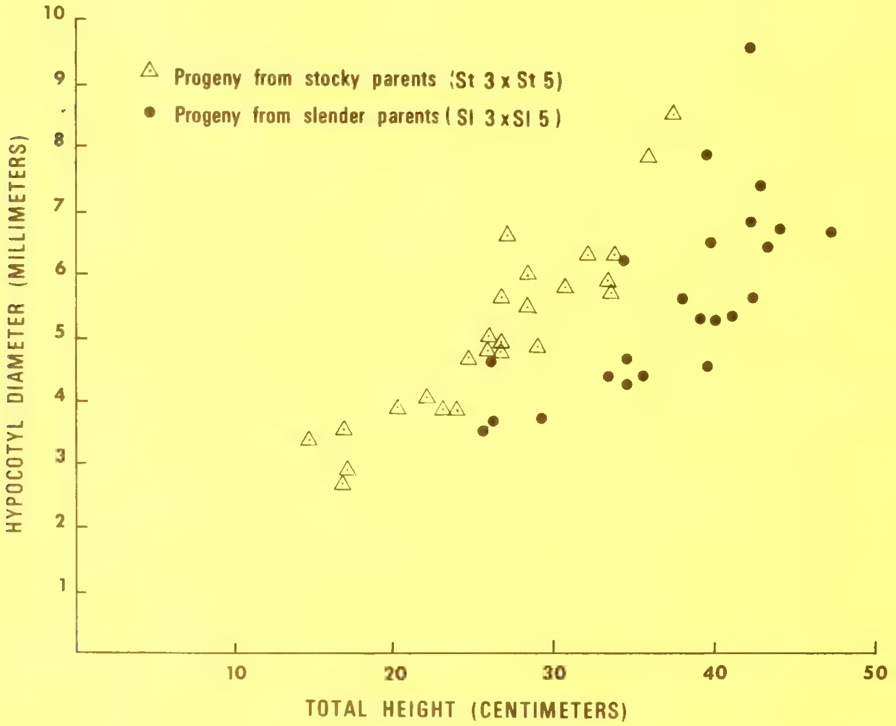

Figure 1.--Seedling height and diameter for a stocky and a slender family from the study illustrate a case in which, at each height, the stocky family consistently has diameter greater than the slender family.

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[1] R. H. Weidman. Evidences of racial influence in a 25-year test of ponderosa pine. J. Agr. Res. 59: 855-887, illus. 1939.

[2] A. E. Squillace and R. R. Silen. Racial variation in ponderosa pine. Forest Sci. Monogr. 2, 27 p. 1962.

over diameter could be an important volume component of inherent growth differences, particularly if the trait is as highly heritable for families as initially estimated for races.

METHODS

In 1964, seven pairs of adjacent open-grown parents about 40 years old were selected at 3,800-foot elevation in the Kiwa Springs area near Bend, Oregon, for striking phenotypic difference in stem form[3]. The more stocky parent-tree of each pair was larger in diameter and had distinctly more volume than the more slender parent-tree, even though it was generally shorter or of nearly equal height (table 1). Past height and diameter of each parent at 5-year intervals was estimated from stem analyses.

In April, pollen-proof bags were placed over female strobili on 10 trees that were flowering in 1964 (pairs 3, 4, 5, and 6, plus stocky parent 1 and slender parent 7). There was sparse flowering in some parents, and it was possible to make only part of the possible crosses and mixed pollen matings as listed in table 2. Seed, collected in October 1966, included nine wind-pollinated lots.

Seedlings were grown 3 years in coldframes at 2- by 2-inch spacing. Total heights and caliper at a point 1 cm. below the cotyledons were made yearly, but only data for age 3 years are reported here. Twenty-seven seedlings were measured in most families, and families with fewer than 15 survivors were not analyzed.

Objectives of the analysis were to ascertain if there were inherent differences in diameters of a family for seedlings of average height (31.25 cm.), if stocky parents produced inherently stockier offspring, if any such differences were closely related to family height, and if a useful component of family volume differences was related to inherent stockiness.

Relationship between seedling height and diameter was nonlinear and variability in diameter increased with height (see fig. 1, for example). An extensive investigation of possible transformations suggested that the linear

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[3] Dr. Carl Berntsen, then project leader, and Walter Dahms, now project leader, of the Silvicultural Laboratory, Bend, Oregon, selected and made stem analysis of parent trees, assisted with pollinations, and otherwise expedited the study.

Table 1.--*Tree measurements of stocky-slender ponderosa pine parents, December 1966*

Pair number	Tree	Volume[1]	D.b.h., d.i.b.	Total height
		Cubic feet	*Inches*	*Feet*
1	Stocky 1	14.4	12.0	37.8
	Slender 1	10.9	9.3	44.1
2	Stocky 2	29.3	14.5	50.6
	Slender 2	18.6	12.4	50.5
3	Stocky 3	27.6	17.1	36.9
	Slender 3	20.6	13.2	48.8
4	Stocky 4	37.3	18.3	54.9
	Slender 4	18.8	12.8	48.2
5	Stocky 5	34.5	16.8	52.6
	Slender 5	26.7	14.1	55.0
6	Stocky 6	14.6	12.4	36.9
	Slender 6	8.9	9.3	36.6
7	Stocky 7	31.5	14.5	55.1
	Slender 7	23.1	12.8	56.1
Average	Stocky	27.03	15.09	46.40
Average	Slender	18.23	11.99	48.47

[1] Total wood volume inside bark from ground to terminal bud estimated from stem analysis.

regression of inverse diameter on height was the best method of adjusting the diameters of different families to an expected diameter at a common height. Stockiness (or slenderness) was then analyzed as predicted inverse diameter at a height of 31.25 cm. Family mean volume was calculated from heights and diameters of individual seedlings by considering the seedling to be conical in form.

Since only a fraction of the possible crosses were made, it was necessary to use a least squares analysis to obtain estimates of the average

Table 2.--*Height, diameter, diameter at 31.25-centimeter height, and volume of 3-year-old families studied for stockiness trait*

Parents	Stocky x stocky				Slender x slender				Combined			
	Height	Diameter	Diameter @ 31.25 cm.	Volume	Height	Diameter	Diameter @ 31.25 cm.	Volume	Height	Diameter	Diameter @ 31.25 cm.	Volume
	Cm.	Mm.	Mm.	Cu. cm.	Cm.	Mm.	Mm.	Cu. cm.	Cm.	Mm.	Mm.	Cu. cm.
1x4	37	7.6	6.1	6.3	--	--	--	--	--	--	--	--
1x5	26	5.5	5.8	3.1	--	--	--	--	--	--	--	--
3x4	34	5.9	5.0	3.7	33	5.4	4.6	2.9	--	--	--	--
3x5	25	4.7	5.8	1.7	37	5.7	4.5	3.5	--	--	--	--
3x7	--	--	--	--	33	4.9	4.1	2.8	--	--	--	--
4x3	31	5.4	5.1	2.7	--	--	--	--	--	--	--	--
4x5	35	5.9	4.6	3.7	--	--	--	--	--	--	--	--
4x6	33	5.4	5.1	2.8	--	--	--	--	--	--	--	--
5x4	--	--	--	--	36	5.5	4.2	3.6	--	--	--	--
5x6	--	--	--	--	34	5.4	4.7	4.0	--	--	--	--
5x7	--	--	--	--	37	5.2	3.9	3.1	--	--	--	--
6x4	--	--	--	--	36	5.8	4.5	3.6	--	--	--	--
6x5	--	--	--	--	32	4.7	4.1	2.2	--	--	--	--
6x7	--	--	--	--	32	5.4	5.1	2.7	--	--	--	--
7x6	--	--	--	--	32	5.5	5.1	2.9	--	--	--	--
1xM[1]	30	6.0	5.4	3.6	--	--	--	--	--	--	--	--
3xM	24	4.1	4.8	1.2	--	--	--	--	--	--	--	--
3xM[2]	--	--	--	--	34	5.4	4.4	3.5	--	--	--	--
4xM	35	5.7	4.2	4.1	--	--	--	--	--	--	--	--
5xM	38	6.5	5.1	4.7	30	5.0	4.8	2.2	--	--	--	--
6xM	33	5.6	4.8	3.0	27	4.9	5.2	2.1	--	--	--	--
7xM	--	--	--	--	29	4.8	4.9	[illegible]	--	--	--	--
1xOP[3]	33	5.9	5.1	3.4	--	--	--	--	--	--	--	--
3xOP	35	5.5	4.8	3.3	33	4.6	4.1	2.2	--	--	--	--
4xOP	36	5.4	4.2	3.6	--	--	--	--	--	--	--	--
5xOP	35	5.8	5.2	3.4	36	4.9	4.2	2.5	--	--	--	--
6xOP	27	4.7	5.1	1.8	30	4.9	4.7	2.2	--	--	--	--
7xOP	--	--	--	--	31	5.3	5.0	2.8	--	--	--	--
Sl3xSt3[4]	--	--	--	--	--	--	--	--	27	4.6	5.2	1.8
Sl5xSt5	--	--	--	--	--	--	--	--	36	5.0	3.9	2.7
Sl7xSt4	--	--	--	--	--	--	--	--	38	5.9	4.3	4.0
St6xSl4	--	--	--	--	--	--	--	--	39	6.8	4.7	5.5
St6xSl6	--	--	-	--	--	--	--	--	30	5.0	4.8	2.3
St6xSlM	--	--	--	--	--	--	--	--	32	5.0	4.6	2.4

[1] A pollen mix of stocky parents 3, 4, 5, and 6 used on all crosses with stocky female parents.

[2] A pollen mix of slender parents 1, 5, 6 and 7 used on all crosses with slender female parents.

[3] Open-pollinated.

[4] Slender parent is designated Sl and stocky parent St in mixed parentage matings.

diameter, stockiness, height, and volume of families of each parent. It was not possible to estimate or adjust for the effects of the specific combinations of parents. A listing of family means for the crosses involving each parent and contrasts between four completed pairs are presented in table 3.

Table 3.--*Least-squares estimates of family means of crosses involving stocky or slender parents, mixed pollen matings, open pollinations, and pair differences. Differences are shown for the four complete pairs.*

Parents[1]	Hypocotyl diameter	Adjusted diameter at 31.25 cm. height		Height	Volume
		Inverse	Actual		
	Mm.	----------*Mm.*---------		*Cm.*	*Cu. cm.*
St1	6.16	0.1735	5.76	30.5	3.90
St3	4.93	.1878	5.32	27.7	2.16
St4	5.99	.2184	4.58	36.1	4.06
St5	5.55	.2037	4.91	32.7	3.16
St6	5.37	.2016	4.96	31.6	2.82
Sl3	5.16	.2284	4.38	33.2	2.87
Sl4	6.06	.2168	4.61	36.0	4.16
Sl5	5.30	.2283	4.38	34.4	3.01
Sl6	5.27	.2040	4.90	30.9	2.65
Sl7	5.41	.2122	4.71	32.7	3.05
StMix	5.45	.2193	4.56	33.0	3.22
SlMix	5.18	.2038	4.91	30.5	2.69
Open	5.22	.2167	4.61	33.0	2.83
Pair differences (stocky minus slender)					
3	-.24	-.0406***	+.94	-5.50*	-.71
4	-.07	+.0015	-.03	+.07	-.11
5	+.25	-.0245*	+.53	-1.78	+.15
6	+.10	-.0025	+.06	+.74	+.17
Average	+.01	-.0165***	+.39	-1.62	-.12

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[1] Slender parent is designated Sl and stocky parent St.

* $P < 0.05$.

*** $P < 0.001$.

Linear regressions of log-volume on height were calculated and are presented in table 4. Comparisons of separate regressions for each of the five family types indicated that there was no significant difference between them and a common regression coefficient was therefore appropriate. Comparisons of volume are the comparisons between the intercepts of the prediction equation.

Table 4.--*Log$_e$ volume regressed on height with a common regression coefficient and predicted volume at 31.25-centimeter height*

Family type	Number of families	Predicition equation for log$_e$ volume[1]	Predicted volume at 31.25-cm. height
Stocky crosses	12	$-1.304 + 0.077$ H	3.01
Slender crosses	14	$-1.507 + .077$ H	2.46
Stocky x slender crosses	6	$-1.522 + .077$ H	2.42
Open-pollinated stocky	5	$-1.454 + .077$ H	2.59
Open-pollinated slender	4	$-1.616 + .077$ H	2.20

[1] H = height in centimeters.

RESULTS

Other than inheritance, there was no reason to expect significant variation in the average family diameters of seedlings of average height (31.25 cm.). Hence, to find in a population of only 10 parent trees such extreme differences as those between height-adjusted diameter of all families from stocky parent 1 (5.76 mm.) and those from slender parent 3 (4.38 mm.) in table 3 is strong evidence that the trait shows appreciable heritable variation from parent to parent in a natural population.

At age 3, families resulting from crosses of stocky parents averaged about 11 percent larger diameter at 31.25-cm. height than families of crossed slender parents. Among the four parental pairs which bore cones, the stocky parent produced significantly stockier offspring in two cases ($P < 0.001$ and $P < 0.05$) and equally stocky progeny in the other two cases. Even actual average diameter of the families reflected the stockiness of the parental type. Overall, the 17 families of various stocky parentage were larger in actual diameters than the 18 families from slender parentage (5.62 mm. vs. 5.18 mm.). Conversely, they were somewhat shorter in height (32.18 cm. vs. 32.88 cm.). The common association of slenderness with tallness and stockiness with shortness, as seen in humans, is thus also displayed in these families. As shown in figure 2, there is a negative relationship of mean family height to mean family diameter adjusted to a common height of 31.25 cm. ($r = -0.47$).

As expected, mean family height and unadjusted diameter was positively related ($r = 0.66$). Although contrast in slope of the two regressions is interesting, the important point is that large height-adjusted diameters commonly occur among tall families. Among the tallest families, for example

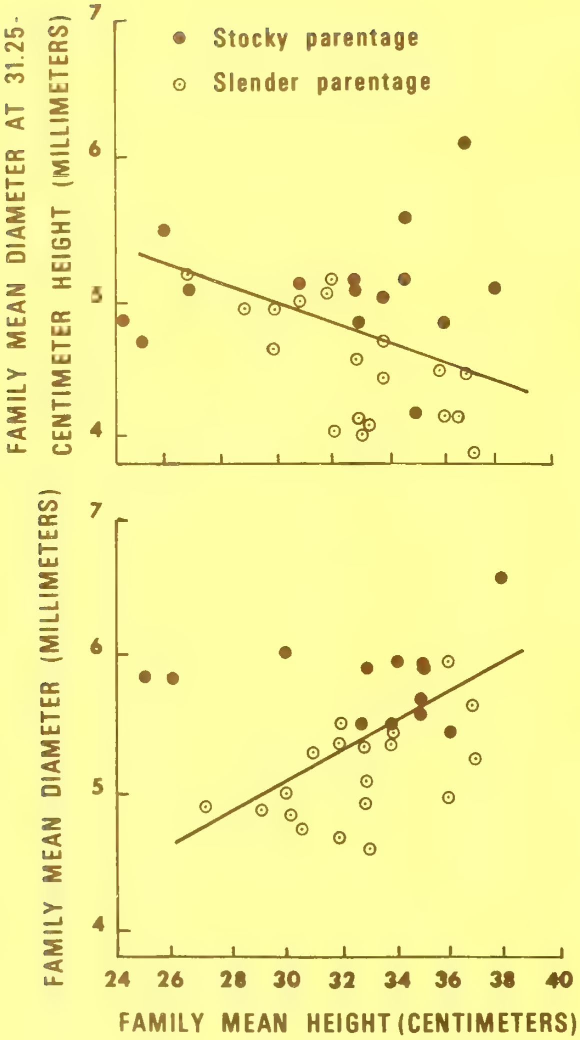

Figure 2.--Relationship of height and diameter at 31.25-cm. height showing slender-tall and stocky-short tendencies of the 41 family means. Average family diameters increase with height as expected.

those over 36 cm. in average height, there occur not only very slender (4.0-mm. diameter) but also very stocky (6.15-mm. diameter) families, suggesting that breeding simultaneously for tallness and stockiness is practical.

Volume of stocky families, when compared for seedlings of equal height, was greater. The common regression applicable for the five types of families allowed the comparison of average log volume of any height as the difference between the intercepts (table 3 and fig. 3). Families of stocky parents had significantly more volume than did families of slender parents ($P < 0.01$), open-pollinated slender female parents ($P < 0.01$), or crosses of stocky with slender parents ($P < 0.05$). When compared at a height of 31.25 cm., the expected average volume of families of stocky parents was 22 percent greater than for families of slender parents, whereas unadjusted average volumes averaged only 2 percent greater. Two other comparisons seem worthy of mention to show consistency of the trait, although they are not statistically significant. When both parents were stocky, volume was 16 percent greater for their offspring than for families of open-pollinated stocky parents, and families of open-pollinated stocky parents had 18 percent more volume than families of open-pollinated slender parents. About 19 percent of the total deviation of volumes from the common slope of regression on height was attributable to the five parental types shown in table 4.

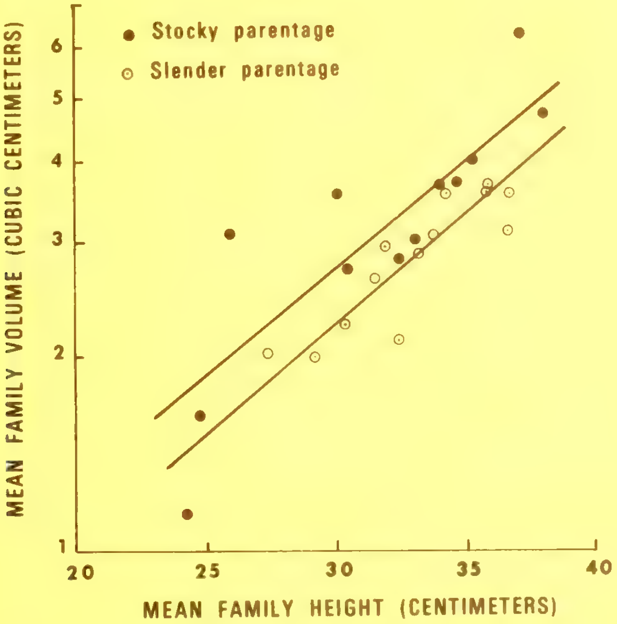

Figure 3.--Mean family volume versus height of crosses among stocky and slender parents.

These observations suggest appreciable correlation between 40-year-old parents and 3-year-old offspring. Attempts to directly relate 1966 parental diameter to the height-adjusted measure of offspring stockiness were singularly unsuccessful ($r = -0.09$). However, since yearly parental heights and diameters were estimated from stem analyses, a number of other measurements were tried as linear predictors of family stockiness. Surprisingly, no parental function of diameters or volumes was highly correlated to family stockiness. For example, relationship of estimated parental diameter as a common height of 40 feet with corresponding height-adjusted family diameters approached but did not quite attain significance ($r = 0.54$ with 8 degrees of freedom). However, functions of heights alone at various ages were highly related, i.e., good height growth of the parent was related to family slenderness. The most effective use of a height function regressed on family stockiness appears to be in the form of growth rate as linear and quadratic regression coefficients for height regressed on age. Regression on the linear coefficients accounts for 80 percent of the variation in offspring family stockiness. The addition of the quadric coefficients--a measure of the acceleration or deceleration in height growth--accounts for a surprising 91 percent of the variation. Nonetheless, these parent-offspring relationships, based on so few parent trees, should be considered primarily for their suggestion value in future research.

Selection of parent trees, even with the restriction of having to find adjacent pairs of trees of similar height, appears to have been fairly effective in identifying genetic differences in the trait.

For the seven pairs, stocky parent trees were about 30 percent stockier than slender parent trees, and families of stocky parents appeared to be about 22 percent stockier than slender families. Thus, it appears that about two-thirds of the differences in the adult stockiness trait was inherited as juvenile differences. However, the intraclass correlation is 0.46. The latter estimate is reasonably close to the heritability of 0.41 estimated by Squillace and Silen (see footnote 2) for racial differences.

Future selections might be even more effective if a wind-pollinated nursery test could be used to screen parents. Wind-pollinated families in the study reflect inherent taper differences seen in outcrossed families ($r^2 = 0.72$ based on nine comparisons).

DISCUSSION

With inheritance of the stockiness trait tentatively verified from individual ponderosa pine parents as well as races, and the trait seemingly so potentially responsive to simple selection, several new questions become important.

Are stocky families necessarily shorter? Although the highly significant regression in figure 2 would suggest so, only 43 percent of the relationship is explained by the regression. Squillace and Silen (see footnote 2) also found height and taper to be of low correlation in racial data. Of importance to the forester, however, are the plentiful exceptions. Of the 17 outcrossed families, for example, the two tallest were from stocky parentage and among the highest in volume and stockiness. The indication here is that there need be no penalty in selecting the tall stocky type except, perhaps, that stockiness may be associated with limbiness. Of course, it remains to be seen whether this combination of traits will remain true for adult volume, or whether the tall stocky type is desirable in terms of adult volume per acre.

Will stockiness or slenderness persist in these families to maturity? Selection in 40-year-old parents was effective in reproducing the same trait in the seedling family, an indicator of appreciable juvenile-mature correlation. Squillace and Silen (see footnote 2) provide data from 1939-56 observations on ponderosa pine races to show a high correlation ($r = 0.77$, computed from data in their table 10, page 20) of the trait measured over a 17-year interval. Presumably the trait is fairly stable. Long-term observation of the families of our study now planted in spacing tests near Bend will ultimately provide juvenile-mature correlations.

If we speculate further, a most important and basic question concerns relationships between inherent growth rates and inherent differences in stockiness. Can the effective selection for differences in stockiness as demonstrated in this study provide a shortcut for selection for better volume growth? Tree volume is more influenced by diameter than by height. As figure 3 shows, selection for stockiness alone provided increased volumes, accounting for about 19 percent of the family volume deviation from the common regression. No similar increases would have resulted from parental selections based upon height, diameter, or volume.

It seems inevitable that a metric trait like tree volume growth will be partitioned into components for more effective selection. Thus, this study suggests that in addition to selection for superior height, a further selection for the stockiness component might improve efficiencies for volume breeding. Perhaps some of inherent volume growth differences observed in other studies reflect this component. These conjectures depend ultimately on the outcome of the question, "Assuming equal heights, can equal numbers of stocky or slender trees grow on an acre?" Even though the 3-year-old seedlings displayed family differences in stockiness at equal spacing, only long-term observation of stocky and slender families at various spacings will provide a final answer. Meanwhile, the trait deserves more exploration by the tree breeder.

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VOLUME TABLES AND EQUATIONS FOR OLD-GROWTH WESTERN REDCEDAR AND ALASKA-CEDAR IN SOUTHEAST ALASKA

by

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ABSTRACT

Separate cubic-foot volume tables are given for western redcedar (*Thuja plicata* Donn) and Alaska-cedar (*Chamaecyparis nootkatensis* (D. Don) Spach). Board-foot tables are given for both species combined.

Keywords: Tree volume tables, tree volume measurement, western redcedar, Alaska-cedar.

Over the past several years double entry volume tables and equations have been developed for most of the major tree species in Alaska (Haack 1963a and 1963b, Gregory and Haack 1964, Embry and Haack 1965, Farr 1967, Bones 1968, Dippold and Farr 1971). Equations for these tables were derived using weighted linear regression of the form first used by Haack (1963a) and later more fully described by Gregory and Haack (1964).

Suitable volume tables were lacking for the two cedars of southeast Alaska, western redcedar (*Thuja plicata* Donn) and Alaska-cedar (*Chamaecyparis nootkatensis* (D. Don) Spach). The value of these

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species has increased substantially in recent years to where they presently command an average round-log value higher than any other Alaskan tree species. The volume tables presented here were developed to more accurately describe these valuable cedars. All existing tree measurement data were screened and compiled, and the resulting volume equations and tables are presented here.

METHODS

Basic tree measurements came from data collected some years ago by Kimmey (1956), data collected recently by Laurent,[1] and data gathered over the years in timber management research.

Western redcedar ranged in diameter from 6 to 66 inches with heights up to 158 feet. Alaska-cedar was smaller with diameters from 5 to 28 inches and heights up to 107 feet.

Points of stem measurement were not consistent among all data, so graphic or computer interpolation techniques were used to obtain necessary upper stem diameters.

Smalian's formula was used to compute cubic volume for 16.3-foot[2] logs between the top of the butt log and the 4-inch top inside bark. For butt logs, diameter inside bark at the 1-foot stump, breast height, and at the 9.15-foot point were also used for cubic volume calculations so that volume of the butt logs could be more accurately determined. International 1/4-inch and Scribner scales were used to compute board-foot volumes for 16.3-foot logs to the 40-percent[3] and 6-inch tops (inside bark).

Weighted linear regression was used to develop volume prediction equations. The weighted combined variable equation used was of the form used previously to develop volume equations for Alaska's tree species. That is:

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[1] Thomas H. Laurent. Cull study for coastal Alaska commercial tree species, 1967. Study plan on file at the Inst. N. Forest., Juneau, Alaska.

[2] Includes 0.3-foot trim allowance.

[3] A top equaling 40 percent of d.b.h. but not less than 6.0 inches inside bark.

$$\frac{V}{D^2H} = \frac{b_0}{D^2H} + \frac{b_1}{DH} + \frac{b_2}{H} + \frac{b_3}{D^2} + b_4 + \frac{b_5}{D^4H}$$

or unweighted:

$$V = b_0 + b_1D + b_2D^2 + b_3H + b_4D^2H + \frac{b_5}{D^2}$$

Separate equations were developed for each species-volume combination. Tests using analysis of covariance indicated that separate cubic-foot volume equations were needed for western redcedar and Alaska-cedar, but that all board-foot volume data for the two species could be pooled. Separate cubic-foot volume tables were then prepared for each species (tables 1-6). For board-foot volume tables, data for both species were pooled (tables 7-14). The weighted equations used and their precision are given in footnote 1 of each volume table.

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height, Smalian's formula, for western redcedar, southeast Alaska[1]

D.b.h. (*D*)[2]	Total height in feet (*H*)[3]															Basis: trees measured[4]
	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	
Inches																*Number*
6	2.3	2.7	3.2	3.6	4.1											10
8	4.9	5.7	6.6	7.4	8.2											7
10	8.1	9.4	10.6	11.9	13.2	14.4	15.7									5
12	11.9	13.7	15.5	17.3	19.2	21.0	22.8	24.6								3
14		18.8	21.2	23.7	26.2	28.7	31.2	33.7								5
16			27.8	31.1	34.3	37.5	40.8	44.0	47.3							1
18			35.3	39.4	43.5	47.6	51.7	55.8	59.9	64.0						10
20			43.6	48.6	53.7	58.8	63.8	68.9	74.0	79.0						12
22			52.7	58.9	65.0	71.1	77.3	83.4	89.5	95.7						7
24			62.8	70.1	77.4	84.7	92.0	99.3	107	114						9
26			73.7	82.3	90.8	99.4	108	117	125	134	142					9
28				95.4	105	115	125	135	145	155	165	175				6
30				110	121	132	144	155	167	178	189	201	212			10
32				125	138	151	164	177	190	202	215	228	241			13
34					155	170	185	199	214	229	243	258	272	287		9
36					174	191	207	223	240	256	273	289	306	322	338	14
38					194	212	231	249	267	286	304	322	340	359	377	9
40					215	235	256	276	296	316	337	357	377	397	418	6
42					237	259	282	304	326	349	371	393	416	438	461	10
44					260	285	309	334	358	383	407	432	456	481	505	5
46							338	365	392	418	445	472	499	526	552	5
48							368	397	426	456	485	514	543	572	602	6
50							399	431	463	494	526	558	589	621	653	--
52							432	466	500	535	569	603	637	672	706	7
54							466	503	540	577	614	650	687	724	761	2
56								541	580	620	660	700	739	779	819	--
58								580	623	665	708	750	793	836	878	--
60								621	666	712	757	803	849	894	940	--
62								663	711	760	809	858	906	955	1004	1
64								706	758	810	862	914	966	1017	1069	--
66								751	806	861	917	972	1027	1082	1137	1
68								797	856	914	973	1032	1090	1149	1207	--
70								845	907	969	1031	1093	1155	1217	1279	--

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[1] Based on weighted regression: $V = 0.04578D^2 + 0.001266D^2H - \frac{27.17}{D^2}$. Standard error of estimate = 13.56 cubic feet or 7.09 percent of the mean volume.

[2] 10-inch class includes trees 9.0 to 10.9 inches in diameter.

[3] 80-foot class includes trees 75.1 to 85.0 feet in height.

[4] Number of trees; range of data for 182 trees enclosed by solid lines.

Table 2.--*Cubic-foot volumes (1-foot stump to a 4-inch top d.i.b.) given d.b.h. and total height, Smalian's formula for Alaska-cedar, southeast Alaska*[1]

D.b.h. (*D*)[2]	Total height in feet (*H*)[3]										Basis: trees measured[4]
	30	40	50	60	70	80	90	100	110	120	
Inches											*Number*
6	2.2	3.2	4.2	5.2							6
8	4.2	5.7	7.2	8.8	10.3	11.9					17
10	6.4	8.6	10.8	13.1	15.3	17.5					17
12	9.0	12.1	15.1	18.2	21.3	24.3					10
14			20.2	24.2	28.3	32.3	36.4	40.5			5
16			25.9	31.1	36.3	41.6	46.8	52.0			3
18			32.4	39.0	45.5	52.0	58.5	65.0			5
20			39.7	47.7	55.6	63.6	71.6	79.5			3
22					66.9	76.5	86.0	95.6	105		2
24					79.2	90.5	102	113	125		3
26					92.6	106	119	132	146		--
28						122	138	153	168	184	1
30						140	158	175	193	210	--

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[1] Based on weighted regression: $V = 0.0316H + 0.001911D^2H - \frac{28.78}{D^2}$. Standard error of estimate = 1.91 cubic feet or 7.68 percent of the mean volume.

[2] 10-inch class includes trees 9.0 to 10.9 inches in diameter.

[3] 80-foot class includes trees 75.1 to 85.0 feet in height.

[4] Number of trees; range of data for 72 trees enclosed by solid lines.

Table 3.--*Cubic-foot volumes (1-foot stump to 4-inch top d.i.b.) given d.b.h. and number of logs to a 6-inch top, Smalian's formula, for western redcedar, southeast Alaska*[1]

D.b.h. (*D*)[2]	Merchantable height in 16-foot logs (*H*)[3]										Basis: trees meas-ured[4]
	1	2	3	4	5	6	7	8	9	10	
Inches											*Number*
12	5.0	10.0	15.1	20.1							3
14	6.8	13.7	20.5	27.3	34.2						5
16	8.9	17.9	26.8	35.7	44.6	53.6					1
18	11.3	22.6	33.9	45.2	56.5	67.8					10
20	13.9	27.9	41.8	55.8	69.7	83.7					12
22		33.8	50.6	67.5	84.4	101					7
24		40.2	60.3	80.3	100	121					9
26		47.1	70.7	94.3	118	141					9
28			82.0	109	137	164	191				6
30			94.1	126	157	188	220	251			10
32			107	143	179	214	250	286			13
34			121	161	202	242	282	322	363		9
36			136	181	226	271	316	362	407		14
38			151	201	252	302	352	403	453		9
40			167	223	279	335	391	446	502		6
42			185	246	308	369	431	492	554		10
44			203	270	338	405	473	540	608		5
46				295	369	443	516	590	664		5
48				321	402	482	562	643	723		6
50				349	436	523	610	697	785		--
52					471	566	660	754	849		7
54					508	610	712	813	915		2
56					547	656	765	875	984		--
58					586	704	821	938	1056		--
60					628	753	879	1004	1130		--
62					670	804	938	1072	1206	1340	1
64					714	857	1000	1143	1285	1428	--
66					759	911	1063	1215	1367	1519	1
68					806	967	1129	1290	1451	1612	--
70					854	1025	1196	1367	1538	1709	--

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[1] Based on weighted regression: $V = 0.034867D^2H$. Standard error of estimate = 37.38 cubic feet or 17.23 percent of the mean volume.

[2] 20-inch class includes trees 19.0 to 20.9 inches in diameter.

[3] Computed in 16.3-foot logs between a 1-foot stump and a 6-inch top inside bark.

[4] Number of trees; range of data for 160 trees enclosed by solid lines.

Table 4.--*Cubic-foot volumes (1-foot stump to 4-inch top d.i.b.) given d.b.h. and number of logs to a 6-inch top, Smalian's formula, for Alaska-cedar, southeast Alaska*[1]

D.b.h. (*D*)[2]	Merchantable height in 16-foot logs (*H*)[3]							Basis: trees measured[4]
	1	2	3	4	5	6	7	
Inches								*Number*
12	8.0	15.9	23.9	31.9				10
14	9.7	19.3	29.0	38.6	48.3			5
16	11.6	23.2	34.8	46.4	58.0			3
18	13.8	27.6	41.4	55.3	69.1			5
20	16.3	32.6	48.8	65.1	81.4			3
22		38.0	57.0	76.0	95.0	114		2
24		44.0	66.0	88.0	110	132		3
26			75.7	101	126	151	177	--
28			86.2	115	144	172	201	1
30			97.5	130	163	195	228	--

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[1] Based on weighted regression: $V = 3.2982H + 0.032452D^2H$. Standard error of estimate = 4.43 cubic feet or 9.64 percent of the mean volume.

[2] 20-inch class includes trees 19.0 to 20.9 inches in diameter.

[3] Computed in 16.3-foot logs between a 1-foot stump and a 6-inch top inside bark.

[4] Number of trees; range of data for 32 trees enclosed by solid lines.

Table 5.--*Cubic-foot volumes (1-foot stump to 4-inch top, d.i.b.) given d.b.h. and number of logs to a 40-percent top, Smalian's formula, for western redcedar, southeast Alaska*[1]

D.b.h. (*D*)[2]	Merchantable height in 16-foot logs (*H*)[3]							Basis: trees measured[4]
	1	2	3	4	5	6	7	
Inches								*Number*
12	12.0	17.8	23.7	29.5				3
14	15.1	23.1	31.0	39.0	47.0			5
16	18.6	29.0	39.4	49.8	60.2			1
18	22.3	35.5	48.7	61.9	75.0	88.2		10
20	26.4	42.7	59.0	75.2	91.5	108		12
22	30.9	50.6	70.2	89.9	110	129		7
24	35.6	59.1	82.5	106	129	153		9
26	40.7	68.2	95.7	123	151	178		9
28	46.1	78.0	110	142	174	206		6
30	51.9	88.5	125	162	198	235	271	10
32	57.9	99.6	141	183	225	266	308	13
34	64.3	111	158	205	252	299	346	9
36	71.0	124	176	229	282	335	387	14
38	78.1	137	196	254	313	372	430	9
40	85.4	150	216	281	346	411	476	6
42	93.1	165	237	308	380	452	524	10
44		180	259	337	416	495	574	5
46		196	282	368	454	540	626	5
48		212	306	399	493	587	680	6
50		229	330	432	534	635	737	--
52			356	466	576	686	796	7
54			383	502	620	739	858	2
56			411	539	666	794	921	--
58			440	577	714	850	987	--
60			470	616	763	909	1055	--
62			501	657	813	970	1126	1
64			532	699	865	1032	1199	--
66			565	742	919	1096	1274	1
68			599	787	975	1163	1351	--
70			633	833	1032	1231	1431	--

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[1] Based on weighted regression: $V = 0.5088D + 0.040668D^2H$. Standard error of estimate = 16.40 cubic feet or 7.56 percent of the mean volume.

[2] 20-inch class includes trees 19.0 to 20.9 inches in diameter.

[3] Computed in 16.3-foot logs between a 1-foot stump and a top equaling 40 percent of d.b.h., but never less than 6.0 inches inside bark.

[4] Number of trees; range of data for 160 trees enclosed by solid lines.

Table 6.--*Cubic-foot volumes (1-foot stump to 4-inch top, d.i.b.) given d.b.h. and number of logs to a 40-percent top, Smalian's formula, for Alaska-cedar, southeast Alaska*[1]

D.b.h. (D)[2]	Merchantable height in 16-foot logs (H)[3]					Basis: trees measured[4]
	1	2	3	4	5	
Inches						*Number*
12	7.8	15.6	23.4	31.2		10
14	9.9	19.8	29.7	39.6	49.5	5
16	12.3	24.6	37.0	49.3	61.6	3
18	15.1	30.1	45.2	60.2	75.3	5
20		36.2	54.3	72.4	90.6	3
22		43.0	64.5	86.0	107	2
24		50.4	75.6	101	126	3
26		58.4	87.7	117	146	--
28		67.1	101	134	168	1
30		76.5	115	153	191	--

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[1] Based on weighted regression: $V = 2.0180H + 0.040236D^2H$. Standard error of estimate = 3.81 cubic feet or 8.31 percent of the mean volume.

[2] 20-inch class includes trees 19.0 to 20.9 inches in diameter.

[3] Computed in 16.3-foot logs between 1-foot stump and a top equaling 40 percent of d.b.h., but not less than 6.0 inches inside bark.

[4] Number of trees; range of data for 32 trees enclosed by solid lines.

Table 7.--*Board-foot volumes (1-foot stump to 6-inch top d.i.b.) given d.b.h. and total height, International 1/4-inch scale, for western redcedar and Alaska-cedar, southeast Alaska*[1]

D.b.h. (*D*)[2]	Total height in feet (*H*)[3]															Basis: trees measured[4]	
	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	Red-cedar	Alaska-cedar
Inches																*Number*	
12	13	40	68	95	123	150	178	205								3	10
14	18	51	84	117	150	183	216	249								5	5
16			104	144	183	222	262	301	341							1	3
18			129	175	222	269	315	362	409	455						10	5
20			157	212	267	322	377	431	486	541						12	3
22			191	254	318	382	445	509	573	637						7	2
24			228	301	375	448	522	595	669	742						9	3
26			269	354	438	522	606	690	774	859	943					9	--
28				411	507	602	698	794	889	985	1081	1176				6	1
30				473	581	689	797	905	1013	1121	1229	1338	1446			10	--
32				541	662	783	905	1026	1147	1268	1389	1511	1632			13	--
34					749	884	1019	1155	1290	1425	1561	1696	1831	1966		9	--
36					842	992	1142	1292	1442	1593	1743	1893	2043	2193	2343	14	--
38					940	1106	1272	1438	1604	1770	1936	2102	2268	2434	2600	9	--
40					1045	1227	1410	1593	1775	1958	2140	2323	2505	2688	2870	6	--
42					1156	1356	1556	1756	1956	2156	2356	2556	2756	2956	3156	10	--
44					1272	1490	1709	1927	2145	2364	2582	2800	3019	3237	3455	5	--
46							1870	2107	2344	2582	2819	3057	3294	3532	3769	5	--
48							2038	2296	2553	2810	3068	3325	3583	3840	4098	6	--
50							2214	2493	2771	3049	3328	3606	3884	4163	4441	--	--
52							2398	2698	2998	3298	3598	3898	4199	4499	4799	7	--
54							2590	2912	3235	3557	3880	4203	4525	4848	5171	2	--
56								3135	3481	3827	4173	4519	4865	5211	5557	--	--
58								3366	3736	4107	4477	4847	5218	5588	5958	--	--
60								3605	4001	4396	4792	5187	5583	5978	6374	--	--
62								3854	4275	4697	5118	5539	5961	6382	6804	1	--
64								4110	4559	5007	5455	5903	6352	6800	7248	--	--
66								4375	4851	5327	5803	6279	6755	7231	7707	1	--
68								4649	5154	5658	6163	6667	7172	7676	8181	--	--
70								4931	5465	5999	6533	7067	7601	8135	8669	--	--

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[1] Based on weighted regression: $V = -5.8214D + 1.2189H + 0.010647D^2H$. Standard error of estimate = 128.83 board feet or 11.04 percent of the mean volume.

[2] 20-inch class includes tree 19.0 to 20.9 inches in diameter.

[3] 80-foot class includes trees 75.1 to 85.0 feet in height.

[4] Number of trees; range of data for 160 redcedar and 32 Alaska-cedar enclosed by solid lines.

Table 8.--*Board-foot volumes (1-foot stump to 6-inch top d.i.b.) given d.b.h. and total height, Scribner scale, for western redcedar and Alaska-cedar, southeastern Alaska*[1]

D.b.h. (D)[2]	Total height in feet (H)[3]															Basis: trees measured[4]	
	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	Red-cedar	Alaska-cedar
Inches																*Number*	
12	40	54	67	81	94	108	121	135								3	10
14	55	73	92	110	128	147	165	183								5	5
16			120	144	168	191	215	239	263							1	3
18			151	182	212	242	273	303	333	364						10	5
20			187	224	262	299	337	374	411	449						12	3
22			226	272	317	362	407	453	498	543						7	2
24			269	323	377	431	485	539	592	646						9	3
26			316	379	442	506	569	632	695	758	822					9	--
28				440	513	586	660	733	806	880	953	1026				6	1
30				505	589	673	757	841	926	1010	1094	1178	1262			10	--
32				574	670	766	862	957	1053	1149	1245	1340	1436			13	--
34					757	865	973	1081	1189	1297	1405	1513	1621	1729		9	--
36					848	969	1091	1212	1333	1454	1575	1696	1818	1939	2060	14	--
38					945	1080	1215	1350	1485	1620	1755	1890	2025	2160	2295	9	--
40					1047	1197	1346	1496	1646	1795	1945	2094	2244	2394	2543	6	--
42					1155	1319	1484	1649	1814	1979	2144	2309	2474	2639	2804	10	--
44					1267	1448	1629	1810	1991	2172	2353	2534	2715	2896	3077	5	--
46							1781	1978	2176	2374	2572	2770	2968	3165	3363	5	--
48							1939	2154	2370	2585	2800	3016	3231	3447	3662	6	--
50							2104	2337	2571	2805	3039	3272	3506	3740	3974	--	--
52							2275	2528	2781	3034	3287	3539	3792	4045	4298	7	--
54							2454	2726	2999	3272	3544	3817	4090	4362	4635	2	--
56								2932	3225	3519	3812	4105	4398	4691	4985	--	--
58								3145	3460	3774	4089	4403	4718	5032	5347	--	--
60								3366	3703	4039	4376	4712	5049	5385	5722	--	--
62								3594	3953	4313	4672	5032	5391	5750	6110	1	--
64								3830	4213	4596	4979	5362	5745	6127	6510	--	--
66								4073	4480	4887	5295	5702	6109	6516	6924	1	--
68								4323	4756	5188	5620	6053	6485	6917	7350	--	--
70								4581	5040	5498	5956	6414	6872	7330	7788	--	--

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[1] Based on weighted regression: $V = 0.009350D^2H$. Standard error of estimate = 127.26 board feet or 11.63 percent of the mean volume.

[2] 20-inch class includes trees 19.0 to 20.9 inches in diameter.

[3] 80-foot class includes trees 75.1 to 85.0 feet in height.

[4] Number of trees; range of data for 160 redcedar and 32 Alaska-cedar enclosed by solid lines.

Table 9.--*Board-foot volumes (1-foot stump to 6-inch top d.i.b.) given d.b.h. and number of logs to a 6-inch top, International 1/4-inch scale, for western redcedar and Alaska-cedar, southeastern Alaska*[1]

D.b.h. (*D*)[2]	Merchantable height in 16-foot logs (*H*)[3]									Basis: trees measured[4]	
	1	2	3	4	5	6	7	8	9	Red-cedar	Alaska-cedar
Inches										*Number*	
12	41	82	122	163						3	10
14	50	101	151	201	252					5	5
16	61	123	184	245	307	368				1	3
18	74	147	221	295	369	442				10	5
20	88	175	263	351	438	526				12	3
22		206	309	412	515	618				7	2
24		240	360	479	599	719				9	3
26		276	415	553	691	829				9	--
28			474	632	790	948	1106			6	1
30			538	717	896	1075	1254	1433		10	--
32			606	807	1009	1211	1413	1615		13	--
34			678	904	1130	1356	1582	1808	2034	9	--
36			755	1007	1258	1510	1762	2013	2265	14	--
38			836	1115	1394	1672	1951	2230	2509	9	--
40			922	1229	1536	1844	2151	2458	2766	6	--
42			1012	1349	1687	2024	2361	2698	3036	10	--
44			1106	1475	1844	2213	2582	2950	3319	5	--
46				1607	2009	2410	2812	3214	3616	5	--
48				1745	2181	2617	3053	3489	3925	6	--
50				1888	2360	2832	3304	3776	4248	--	--
52					2547	3056	3565	4075	4584	7	--
54					2741	3289	3837	4385	4933	2	--
56					2942	3531	4119	4707	5296	--	--
58					3151	3781	4411	5041	5671	--	--
60					3367	4040	4713	5387	6060	--	--
62					3590	4308	5026	5744	6462	1	--
64					3821	4585	5349	6113	6877	--	--
66					4059	4870	5682	6494	7305	1	--
68					4304	5165	6025	6886	7747	--	--
70					4556	5468	6379	7290	8202	--	--

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[1] Based on weighted regression: $V = 14.4466H + 0.183029D^2H$. Standard error of estimate = 129.05 board feet or 11.06 percent of the mean volume.

[2] 20-inch class includes trees 19.1 to 21.0 inches in diameter.

[3] Computed in 16.3-foot logs between a 1-foot stump and a 6-inch top inside bark.

[4] Number of trees; range of data for 160 redcedar and 32 Alaska-cedar enclosed by solid lines.

Table 10.--*Board-foot volumes (1-foot stump to 6-inch top d.i.b.) given d.b.h. and number of logs to a 6-inch top, Scribner scale, for western redcedar and Alaska-cedar, southeastern Alaska* [1]

D.b.h. (*D*)[2]	Merchantable height in 16-foot logs (*H*)[3]									Basis: trees measured[4]	
	1	2	3	4	5	6	7	8	9	Red-cedar	Alaska-cedar
Inches										*Number*	
12	33	66	99	132						3	10
14	42	84	126	169	211					5	5
16	53	105	158	211	264	316				1	3
18	65	129	194	259	323	388				10	5
20	78	156	234	312	390	468				12	3
22		186	279	371	464	557				7	2
24		218	327	436	545	655				9	3
26		253	380	507	634	760				9	--
28			437	583	729	874	1020			6	1
30			499	665	831	997	1163	1329		10	--
32			564	752	940	1128	1316	1504		13	--
34			634	845	1056	1268	1479	1690	1902	9	--
36			708	944	1180	1416	1652	1888	2124	14	--
38			786	1048	1310	1572	1834	2096	2358	9	--
40			869	1158	1448	1737	2027	2316	2606	6	--
42			955	1274	1592	1910	2229	2547	2866	10	--
44			1046	1395	1744	2092	2441	2790	3138	5	--
46				1522	1902	2283	2663	3043	3424	5	--
48				1654	2068	2481	2895	3308	3722	6	--
50				1792	2240	2689	3137	3585	4033	--	--
52					2420	2904	3388	3872	4356	7	--
54					2607	3128	3650	4171	4692	2	--
56					2801	3361	3921	4481	5041	--	--
58					3002	3602	4202	4803	5403	--	--
60					3210	3851	4493	5135	5777	--	--
62					3424	4109	4794	5479	6164	1	--
64					3646	4376	5105	5834	6564	--	--
66					3876	4651	5426	6201	6976	1	--
68					4112	4934	5756	6579	7401	--	--
70					4355	5226	6097	6968	7839	--	--

[1] Based on weighted regression: $V = 7.5946H + 0.176197D^2H$. Standard error of estimate = 122.66 board feet or 11.21 percent of the mean volume.

[2] 20-inch class includes trees 19.0 to 20.9 inches in diameter.

[3] Computed in 16.3-foot logs between a 1-foot stump and a 6-inch top inside bark.

[4] Number of trees; range of data for 160 redcedar and 32 Alaska-cedar enclosed by

Table 11.--*Board-foot volumes (1-foot stump to 40-percent top) given d.b.h. and total height, International 1/4-inch scale, for western redcedar and Alaska-cedar, southeastern Alaska*[1]

D.b.h. (D)[2]	Total height in feet (H)[3]															Basis: trees measured[4]	
	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	Red-cedar	Alaska-cedar
Inches																*Number*	
12	43	58	72	86	101	115	130	144								3	10
14	59	78	98	118	137	157	176	196								5	5
16			128	154	179	205	230	256	281							1	3
18			162	194	227	259	291	324	356	389						10	5
20			200	240	280	320	360	400	440	480						12	3
22			242	290	339	387	435	484	532	581						7	2
24			288	345	403	461	518	576	633	691						9	3
26			338	405	473	541	608	676	743	811	878					9	--
28				470	549	627	705	784	862	940	1019	1097				6	1
30				540	630	720	810	900	990	1080	1169	1259	1349			10	--
32				614	716	819	921	1024	1126	1228	1331	1433	1535			13	--
34					809	924	1040	1155	1271	1387	1502	1618	1733	1849		9	--
36					907	1036	1166	1295	1425	1555	1684	1814	1943	2073	2202	14	--
38					1010	1155	1299	1443	1588	1732	1876	2021	2165	2309	2454	9	--
40					1120	1279	1439	1599	1759	1919	2079	2239	2399	2559	2719	6	--
42					1234	1411	1587	1763	1940	2116	2292	2469	2645	2821	2997	10	--
44					1355	1548	1742	1935	2129	2322	2516	2709	2903	3096	3290	5	--
46							1904	2115	2327	2538	2750	2961	3173	3384	3596	5	--
48							2073	2303	2533	2764	2994	3224	3454	3685	3915	6	--
50							2249	2499	2749	2999	3249	3498	3748	3998	4248	--	--
52							2433	2703	2973	3243	3514	3784	4054	4325	4595	7	--
54							2623	2915	3206	3498	3789	4081	4372	4664	4955	2	--
56								3135	3448	3762	4075	4388	4702	5015	5329	--	--
58								3363	3699	4035	4371	4708	5044	5380	5716	--	--
60								3598	3958	4318	4678	5038	5398	5757	6117	--	--
62								3842	4227	4611	4995	5379	5763	6148	6532	1	--
64								4094	4504	4913	5322	5732	6141	6551	6960	--	--
66								4354	4790	5225	5660	6096	6531	6967	7402	1	--
68								4622	5084	5546	6009	6471	6933	7395	7857	--	--
70								4898	5388	5877	6367	6857	7347	7837	8326	--	--

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[1] Based on weighted regression: $V = 0.009996D^2H$. Standard error of estimate = 141.82 board feet or 12.71 percent of the mean volume.

[2] 20-inch class includes trees 19.0 to 20.9 inches in diameter.

[3] 80-foot class includes trees 75.1 to 85.0 feet in height.

[4] Number of trees; range of data for 160 redcedar and 32 Alaska-cedar enclosed by solid lines.

Table 12.--*Board-foot volumes (1-foot stump to 40-percent top) given d.b.h. and total height, Scribner scale, for western redcedar and Alaska-cedar, southeastern Alaska*[1]

D.b.h. (*D*)[2]	Total height in feet (*H*)[3]															Basis: trees measured[4]	
	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	Red-cedar	Alaska-cedar
Inches																*Number*	
12	40	53	66	79	92	105	119	132								3	10
14	54	72	90	108	126	143	161	179								5	5
16			117	141	164	187	211	234	258							1	3
18			148	178	208	237	267	297	326	356						10	5
20			183	220	256	293	329	366	403	439						12	3
22			221	266	310	354	399	443	487	532						7	2
24			264	316	369	422	474	527	580	633						9	3
26			309	371	433	495	557	619	681	742	804					9	--
28				430	502	574	646	717	789	861	933	1004				6	1
30				494	577	659	741	824	906	988	1071	1153	1235			10	--
32				562	656	750	843	937	1031	1125	1218	1312	1406			13	--
34					741	846	952	1058	1164	1270	1375	1481	1587	1693		9	--
36					830	949	1067	1186	1305	1423	1542	1660	1779	1898	2016	14	--
38					925	1057	1189	1322	1454	1586	1718	1850	1982	2114	2247	9	--
40					1025	1171	1318	1464	1611	1757	1904	2050	2196	2343	2489	6	--
42					1130	1291	1453	1614	1776	1937	2099	2260	2422	2583	2744	10	--
44					1240	1417	1595	1772	1949	2126	2303	2480	2658	2835	3012	5	--
46							1743	1937	2130	2324	2517	2711	2905	3098	3292	5	--
48							1898	2109	2319	2530	2741	2952	3163	3374	3585	6	--
50							2059	2288	2517	2746	2974	3203	3432	3661	3889	--	--
52							2227	2475	2722	2970	3217	3464	3712	3959	4207	7	--
54							2402	2669	2936	3202	3469	3736	4003	4270	4537	2	--
56								2870	3157	3444	3731	4018	4305	4592	4879	--	--
58								3079	3387	3694	4002	4310	4618	4926	5234	--	--
60								3295	3624	3954	4283	4612	4942	5271	5601	--	--
62								3518	3870	4222	4573	4925	5277	5629	5980	1	--
64								3749	4123	4498	4873	5248	5623	5998	6373	--	--
66								3986	4385	4784	5182	5581	5980	6378	6777	1	--
68								4232	4655	5078	5501	5924	6348	6771	7194	--	--
70								4484	4933	5381	5830	6278	6727	7175	7623	--	--

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[1] Based on weighted regression: $V = 0.009152D^2H$. Standard error of estimate = 131.13 board feet or 12.43 percent of the mean volume.

[2] 20-inch class includes trees 19.1 to 21.0 inches in diameter.

[3] 80-foot class includes trees 75.1 to 85.0 inches in height.

[4] Number of trees; range of data for 160 redcedar and 32 Alaska-cedar enclosed by solid lines.

Table 13.--*Board-foot volumes (1-foot stump to 40-percent top) given d.b.h. and number of logs to a 40-percent top, International 1/4-inch scale, for western redcedar and Alaska-cedar, southeastern Alaska*[1]

D.b.h. (D)[2]	Merchantable height in 16-foot logs (H)[3]							Basis trees measured[4]	
	1	2	3	4	5	6	7	Red-cedar	Alaska-cedar
Inches								*Number*	
12	37	74	112	149				3	10
14	51	101	152	202	253			5	5
16	66	132	198	264	330			1	3
18	84	167	251	335	418	502		10	5
20	103	207	310	413	516	620		12	3
22		250	375	500	625	750		7	2
24		297	446	595	743	892		9	3
26		349	523	698	872	1047		9	--
28		405	607	810	1012	1214		6	1
30		465	697	929	1162	1394	1626	10	--
32		529	793	1057	1322	1586	1850	13	--
34		597	895	1194	1492	1790	2089	9	--
36		669	1004	1338	1673	2007	2342	14	--
38		745	1118	1491	1864	2236	2609	9	--
40		826	1239	1652	2065	2478	2891	6	--
42		911	1366	1821	2277	2732	3187	10	--
44		999	1499	1999	2499	2998	3498	5	--
46		1092	1639	2185	2731	3277	3823	5	--
48		1189	1784	2379	2974	3568	4163	6	--
50		1291	1936	2581	3227	3872	4517	--	--
52			2094	2792	3490	4188	4886	7	--
54			2258	3011	3764	4516	5269	2	--
56			2429	3238	4048	4857	5667	--	--
58			2605	3473	4342	5210	6079	--	--
60			2788	3717	4646	5576	6505	--	--
62			2977	3969	4961	5954	6946	1	--
64			3172	4229	5287	6344	7401	--	--
66			3373	4498	5622	6747	7871	1	--
68			3581	4774	5968	7162	8355	--	--
70			3795	5059	6324	7589	8854	--	--

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[1] Based on weighted regression: $V = 0.258135D^2H$. Standard error of estimate = 106.42 board feet or 9.54 percent of the mean volume.

[2] 20-inch class includes trees 19.0 to 20.9 inches in diameter.

[3] Computed in 16.3-foot logs between a 1-foot stump and a top equaling 40 percent of d.b.h., but not less than 6.0 inches.

[4] Number of trees; range of data for 160 redcedar and 32 Alaska-cedar enclosed by solid lines.

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Table 14.--*Board-foot volumes (1-foot stump to a 40-percent top) given d.b.h. and number of logs to a 40-percent top, Scribner scale, for western redcedar and Alaska-cedar, southeast Alaska*[1]

D.b.h. (D)[2]	Merchantable height in 16-foot logs (H)[3]							Basis: trees measured[4]	
	1	2	3	4	5	6	7	Red-cedar	Alaska-cedar
Inches								*Number*	
12	19	56	92	129				3	10
14	29	79	129	179	229			5	5
16	42	107	172	237	302			1	3
18	56	139	221	303	385	468		10	5
20	73	174	276	378	479	581		12	3
22	91	214	337	460	583	706		7	2
24	112	258	404	551	697	843		9	3
26		306	478	649	821	993		9	--
28		358	557	756	955	1155		6	1
30		414	642	871	1100	1329	1557	10	--
32		474	734	994	1254	1515	1775	13	--
34		538	832	1126	1419	1713	2007	9	--
36		606	936	1265	1594	1924	2253	14	--
38		679	1046	1412	1779	2146	2513	9	--
40		755	1162	1568	1975	2381	2788	6	--
42		835	1284	1732	2180	2628	3077	10	--
44		920	1412	1904	2396	2888	3380	5	--
46		1009	1546	2084	2621	3159	3697	5	--
48		1101	1687	2272	2857	3443	4028	6	--
50		1198	1833	2468	3104	3739	4374	--	--
52			1986	2673	3360	4047	4734	7	--
54			2144	2885	3626	4367	5108	2	--
56			2309	3106	3903	4700	5497	--	--
58			2480	3335	4190	5044	5899	--	--
60			2657	3572	4487	5401	6316	--	--
62			2840	3817	4794	5770	6747	1	--
64			3029	4070	5111	6152	7192	--	--
66			3225	4331	5438	6545	7652	1	--
68			3426	4601	5776	6951	8126	--	--
70			3634	4879	6124	7369	8614	--	--

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[1] Based on weighted regression: $V = -1.4523D + 0.254093D^2H$. Standard error of estimate = 101.45 board feet or 9.62 percent of the mean volume.

[2] 20-inch class includes trees 19.0 to 20.9 inches in diameter.

[3] Computed in 16.3-foot logs between a 1-foot stump and a top equaling 40 percent of d.b.h., but not less than 6.0 inches.

[4] Number of trees; range of data for 160 redcedar and 32 Alaska-cedar enclosed by solid lines.

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USDA FOREST SERVICE RESEARCH NOTE

PNW-168 *November 1971*

A "BATTERY SAVER" FOR EVENT RECORDERS

by

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ABSTRACT

An electronic circuit and device designed to eliminate some of the problems encountered with event recorders in field operations is described.

Keywords: Measuring equipment, transducers, electric batteries.

PROBLEM

Current research practices and instrumentation often include the use of contacting-type transducers. In the collection of such data, it is usually desirable to use event recorders. As an example, the anemometer is typical of contacting-type transducers generally used with event recorders in forestry and related research activities. One problem is that wind movement may cease at such a time as to leave

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the contacts of the anemometer in the closed position. Whether it be anemometers, rain gages, or other transducers used to count events, sometimes the switch would stay in a closed position. When this occurred and when we were interested primarily in the event occurring rather than the duration of the event, it has been our experience that batteries would run down in a very short time. Subsequent loss of data seriously impaired or curtailed a study.

SOLUTION

Several years ago, the U. S. Forest Service developed a totalizing wind counter for contacting-type anemometers. This wind counter and circuit design are discussed in detail in an equipment development report.[1/] A feature of the basic electronic circuit is the capability to prolong battery life. We used this original version of counter on several occasions and then modified it to meet our more specific needs. We did not need the counter capability but used the basic circuitry that had already been developed. Essentially, we removed the digital counter unit from the original circuit and substituted our event recorders, adapting and applying a long-used principle and circuit.

"BATTERY SAVER"

The diagram of the "battery saver" box (fig. 1) consists of two identical control circuits. One of these control circuits is made up of J1, R1, C1, C2, and K1.

J1 is connected to the transducer and is shorted when the transducer contact is closed. When the transducer contacts close, the circuit is complete and energizes resistor R1, relay K1, and capacitor C2. C2 will begin charging at a high current rate which diminishes as the charge voltage of the capacitor approaches the applied battery voltage. Likewise, at the start of the charging period, the current flowing through the coil of relay K1, which is in series with C2, will be sufficient to close the contacts of K1. These relay contacts will remain closed until the current flowing through the coil of K1 is insufficient to hold them closed (12 milliseconds nominal). At that time, the relay contacts of K1 will open. If the transducer contacts remain closed,

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[1/] Intermountain Forest and Range Experiment Station, Division of Forest Fire Research. Totalizing wind counter for contacting-type anemometers. Washington, D. C., Forest Serv., U. S. Dep. Agr. Tech. Equip. Rep. F-2, 6 p., illus., May 5, 1958.

ERRATA SHEET

A "Battery Saver" for Event Recorders, by Richard J. Barney and Thomas C. Van Wickle. USDA Forest Service Research Note PNW-168, 6 pp. illus. 1971.

Add the following parts list to the bottom of Figure 1, page 3.

J1, J2 - Receptacle, phone
J3 - Receptacle, twin banana
R1, R2 - Resistor 500 ohms, 1 watt, wire wound (for 6-volt operation)
1500 ohms, 1 watt, wire wound (for 12-volt operation)
C1, C3 - Capacitor, 0.05 uf., 400 vdc, Mylar
C2, C4 - Capacitor, 100 uf., 50 vdc, Electrolytic
K1, K2 - Relay, Sigma-type 41F-200F SIL
S1 - Switch, Toggle, SPST
D1 - Diode, 1A 1KV PIV

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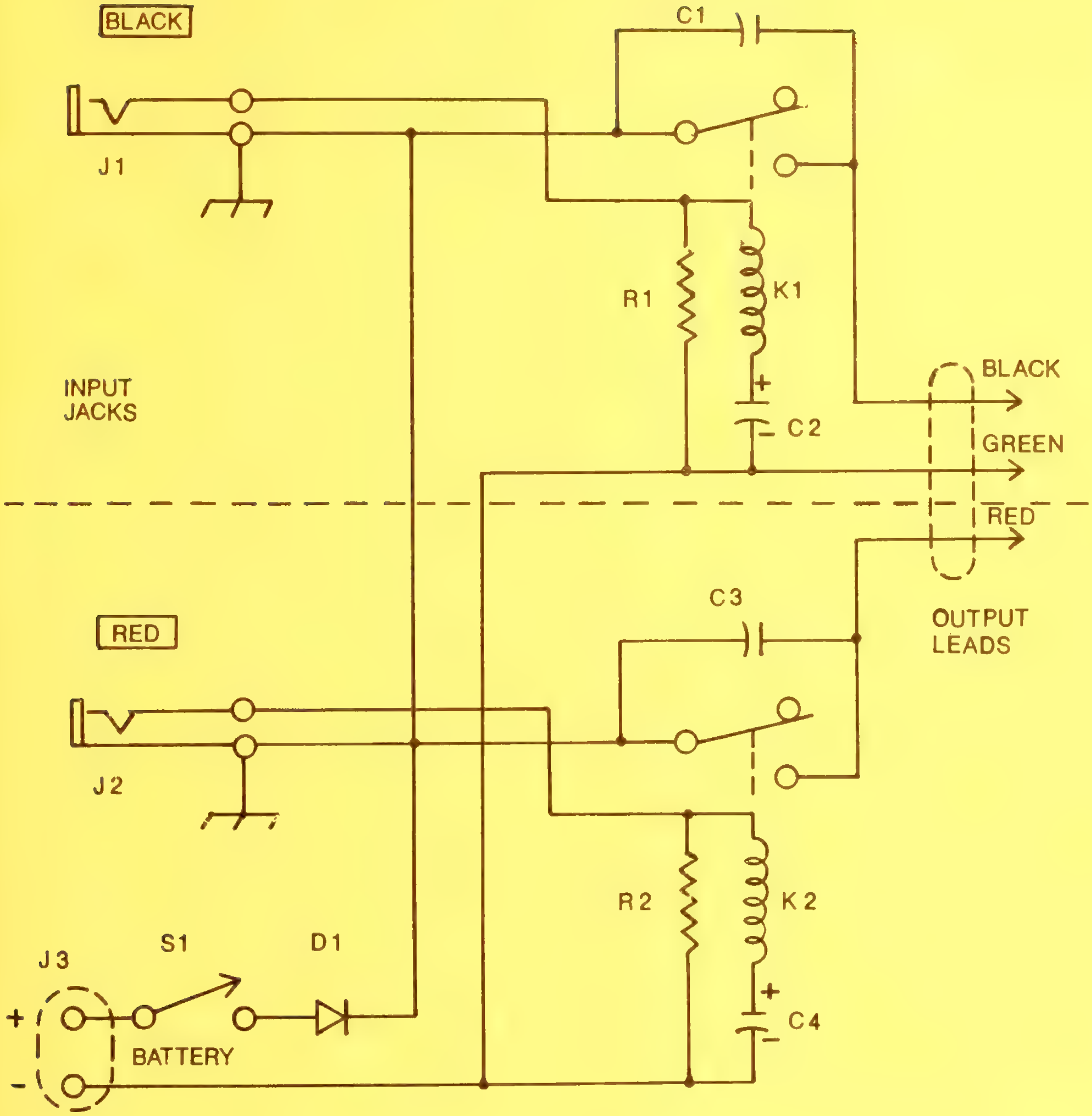

Figure 1.--Diagram of "battery saver" showing dual circuit configuration. Diagram portion above the dotted line is for a single-unit configuration.

C2 remains charged, K1 contacts remain open, and a continuous 10-milliampere (nominal) current is drawn from the battery by the control circuit. When the contacts of the transducer open, power is removed from R1, K1, and C2. C2 then discharges through K1 and R1, but the current is insufficient to cause the contacts of K1 to close again.[2] When the contacts of K1 close, battery power is provided to the output leads. C1 is a spark suppression capacitor used to improve reliability of relay contacts when used to control solenoid-operated devices such as counters and chart recorder pens.

Battery power has an on-off switch and a diode in series. The switch is primarily a convenience, but the diode prevents an incorrectly connected battery's damaging the electrolytic capacitor C2. If the battery is incorrectly connected, the system will not function. Battery polarity must be observed. Depending on the mechanical characteristics of individual relays, the operational reliability will generally drop below 5 volts on the 6-volt version and below 10 volts on the 12-volt version. Under normal operating conditions, the battery drain is usually less than the shelf life of the battery. For insurance, we change the batteries periodically. Compared with lost data, battery replacement costs are minimal.

Since we installed the "battery saver," no data have been lost due to battery failure. The "battery saver" has reduced chatter problems which we have encountered using contacting-type devices. Our experience has shown that the circuit can easily handle 1 pulse per second. As in the case with some of our anemometers, this pulse rate is equivalent to a sustained wind of 60 miles per hour. These units may be built in single or multiple configurations. We have used both types and are currently using several dual circuits and a four-circuit model. In our construction process, we have attempted to provide color coding and external hardware of such a nature as to make field hookups relatively simple. Also we have designed an alternative to making the system adaptable to both 6-volt and 12-volt operations depending upon the requirement of the actuators in the event recorder. This conversion is simply accomplished by changing a resistor (R1). The change could also be handled by a switching arrangement for more convenient substitution of the resistor (R1). Cost of parts on today's market is approximately $11 per circuit. Assembly time is 1 hour for the dual circuit model (fig. 2).

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[2] Caution -- If a 6-volt "battery saver" box is used with a 12-volt battery, the discharge current is sufficient to cause the contacts of K1 to close again when the transducer contacts open and thereby cause a double count. However, no physical damage to the "battery saver" box is caused by such an error. The voltage of the recording device solenoid must equal that of the "batterv saver" voltage used.

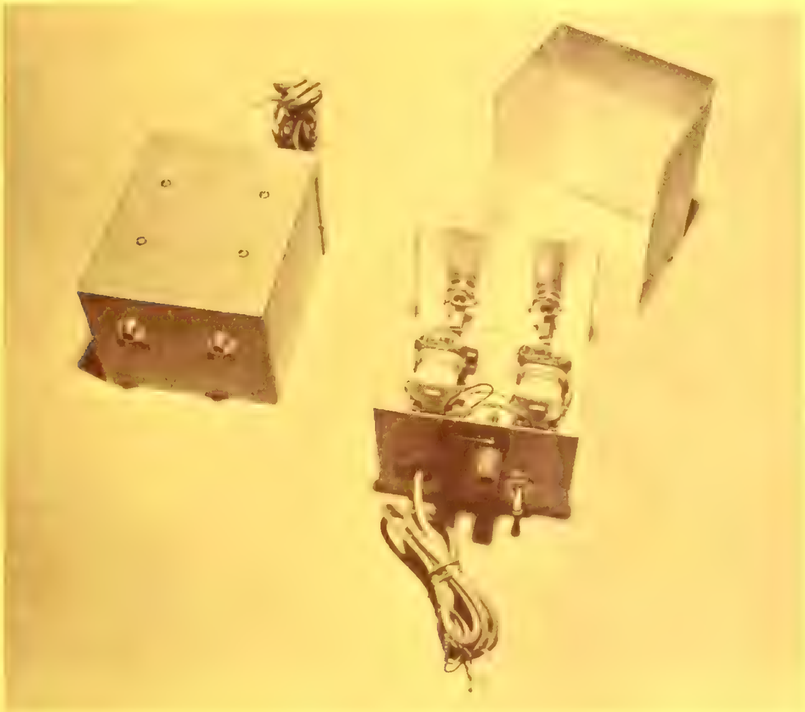

Figure 2.--External and internal views of a dual unit "battery saver."

ADVANTAGES

The advantages of such a circuit are:

1. Battery protection
2. Limit on imput frequency (antichatter)
3. Fixed pulse width on output independent of varying input width -- better identification of individual marks on slow chart.

We have had an equivalent of 9 years of satisfactory experience with a number of anemometers and various types of event recorders used in conjunction with our devices. Inclusion of the "battery saver" with an event recorder results in approximately a 90-percent savings in current drain when the circuit is closed. Table 1 compares two frequently used voltages and recorders as found in our normal field operations.

Table 1.--*Comparison of current flow with and without the battery saver for two recorders*

Recorder type[1]	Operation voltage	Measured current	
		Without battery saver	With battery saver
	Volts direct current	- - - - *Milliamperes* - - - -	
Esterline-Angus event recorder	6	165	12
Rustrak event recorder	12	110	10

[1] Use of brand names is only for convenience and does not constitute endorsement by the U.S. Forest Service.

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USDA FOREST SERVICE RESEARCH NOTE

PNW-169 *November 1971*

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STREAMFLOW NITROGEN LOSS FOLLOWING FOREST EROSION CONTROL FERTILIZATION

by

G. O. Klock, *Soil Scientist*

Abstract

Three gaged watersheds, approximately 500 hectares in size, in north central Washington were severely burned in 1970 by wildfire. In an experimental erosion control seeding program, two watersheds were fertilized, one with urea and the other with ammonium sulfate. The third watershed was retained as an unrehabilitated control. For a 60-day period during and following fertilization, 1.37 kilograms of urea-N and 2.90 kilograms of nitrate-N were estimated to have been carried by streamflow from the watershed fertilized with 27.5 metric tons of elemental nitrogen as urea. On the watershed fertilized with 33.16 metric tons of elemental nitrogen as ammonium sulfate, 1.45 kilograms of nitrate-N was estimated to have been transported from the watershed by streamflow.

Keywords: Aerial fertilization, streamflow records, soil erosion.

INTRODUCTION

Forest fertilization is becoming an operational practice in many areas of the United States. Scientists have been attempting to monitor the fate of this chemical addition to the forest environment (Moore 1970). In recent years, fertilization to enhance early devel-

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opment of introduced and native vegetation (Klock 1969) after wildfire has become an accepted practice in the Cascade Mountains of Washington.

Considerable concern has been expressed over the possible effect on water quality by fertilization during erosion control (Stanford et al. 1970). In forest fertilization for wood production, the application of chemicals in a zone near stream channels can be avoided to prevent both significant chemical loss and the possible deterioration of water quality. Protection of this zone near streams with vegetative cover is most important in forest erosion control. Since fertilizing to develop satisfactory vegetative cover and maintain soil stability appears imperative in many Cascade Mountain watersheds, information is needed on the fertilizer carried by streamflow from watersheds during and following erosion control.

On August 24, 1970, the entire 1,551-hectare Entiat Experimental Forest in north central Washington was severely burned by wildfire. Since the soils are quite infertile and unstable in this important water-producing region, reseeding and fertilization appeared necessary. Thus, a unique opportunity was created to run a controlled test on three gaged watersheds.

STUDY AREA

The Entiat Experimental Forest was set aside in 1957 as a study area representative of much of the forested lands east of the Washington Cascade Mountain crest (Berndt 1971). It is made up of three adjacent watersheds: Fox Creek, Burns Creek, and McCree Creek--473, 564, and 514 hectares in size, respectively, on a generally southwest aspect.

The study area watersheds are within the Entiat River basin, an area characterized by steep and rugged relief dissected by numerous tributary streams. The river valley is the characteristic U-shape of a glacial valley, having been formed by two glacial advances and recessions during the Wisconsin stage of the Pleistocene epoch.[1/] The watersheds, which were relatively unaffected by the glaciation, were left as hanging valleys above the main valley floor. Watershed elevations range from 550 meters to more than 2,100 meters at the headwaters. Mean slope is about 50 percent but slopes as steep as 90 percent are common.

[1/] B. M. Page. Geology of a part of the Chiwaukum quadrangle. 1939. (Unpublished Ph. D. thesis on file at Stanford Univ., Palo Alto, Calif.)

The base rock on the watersheds is an extensive formation known as the Chelan Batholith, a mesozoic intrusive granodiorite with biotite and hornblende as accessory minerals. A medium- to coarse-grained massive rock, the gray granodiorite weathers deeply where exposed. Since glaciation, the area has been periodically covered by volcanic ash and pumice, mostly originating from Glacier Peak (Fryxell 1965) approximately 33 kilometers west-northwest of the study area.

The Choral soil series occupies about 55 percent of the area (Iritani and Meyer 1967). Rampart soils occupy another 30 percent, and rock land or rock outcrops account for 15 percent. Choral soils are well drained, moderately coarse-textured, and derived from volcanic ash and pumice. The surface 60 centimeters is a fine, sandy loam grading to coarse, loamy sand. This is underlain by pure pumice up to 6 meters deep. Rampart soils are very similar to Choral except they occur at lower elevations and have developed under warmer climatic conditions. Total nitrogen levels of surface soils for both are normally below 0.05 percent. Since the fire, considerable carbonized plant material (ash) covers the soil surface, particularly in the stream zones.

Vegetation destroyed by the fire was almost entirely mature virgin forest. Ponderosa pine (*Pinus ponderosa* Laws.) was the main species with Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) as the main associated species. Stocking densities ranged from medium to poor. Common understory species were snowbrush ceanothus (*Ceanothus velutinus* Dougl.), bitterbrush (*Purshia tridentata* (Pursh) DC.), grouse whortleberry (*Vaccinium scoparium* Leib.), and pinegrass (*Calamagrostis rubescens* Buckl.).

The climate is typical of the region with droughty summers and most of the precipitation falling as snow in the winter months. Available records show, at 915-meter elevation, an annual mean temperature of 6.8° C. and an average annual precipitation of 46 centimeters.

Stream channels on all three watersheds are deeply incised and contain quantities of fire debris and decaying logs. Estimated channel lengths for Fox, Burns, and McCree are 3.5, 5.3, and 6.9 kilometers, respectively. Streamflow is characterized by high volumes from snowmelt in May and June with a rapid decline to a low and fairly steady flow by August or September. Streamflow ranges between a low and a high of 0.011 and 0.396 liters per hectare (0.1 to 3.5 cubic feet per square mile).

METHOD

An experimental rehabilitation plan for erosion control was developed and initiated in which Fox Creek watershed was left undisturbed as a control stream. Burns Creek watershed was seeded with a grass mixture and fertilized with 280 kilograms per hectare of ammonium sulfate--a total application of 157.92 metric tons of fertilizer which included 33.16 metric tons of elemental nitrogen. Burns Creek watershed was fertilized in two periods, October 30-31 (21.5 metric tons) and November 9-12 (136.42 metric tons).

McCree Creek watershed was also seeded with a grass mixture and fertilized with 117.6 kilograms per hectare urea--a total application of 59.8 metric tons of fertilizer material which included 27.5 metric tons of elemental nitrogen. Urea was spread in three periods: October 30-31 (4.5 metric tons), November 4-5 (14.5 metric tons), and November 7-8 (40.8 metric tons).

All fertilizer was spread by helicopters with 250-kilogram loads on a grid approximately 24 meters wide. No attempt was made to avoid stream channels.

At the outflow of all three watersheds 4-liter water samples were collected two times before fertilization (October 23 and 29), every 12 hours (0900 and 2100 hours) during the period of fertilization (October 30 to November 12), daily from November 13 to 20, and on November 25, December 1, 7, 10, and 17. Water samples were taken to the laboratory, keeping the sample at or below stream temperature of about 5° C. and stored unfrozen at -0.6° C. until chemical analysis was done.

Urea-N concentrations in the stream water samples were determined by the method proposed by Newell et al. (1967) and modified for fresh water by Moore.[2] Nitrate-N was determined by the cadmium-copper reduction method proposed by Wood et al. (1967) and again modified by Moore. Ammonia-N was analyzed by the Nessler method (Chapman and Pratt 1961).

RESULTS

In the 8 days prior to fertilization, no measurable levels of ammonia-, urea-, or nitrate-N were detected in Burns or McCree Creek. At the beginning of the sampling period October 23, Fox Creek had a urea-N level of 35 parts per billion, with wildlife activity a possible source. This level decreased until it was undetectable after November 11. No ammonia-N or nitrate-N was detected in Fox Creek during the period of analysis October 23 to December 17, 1970.

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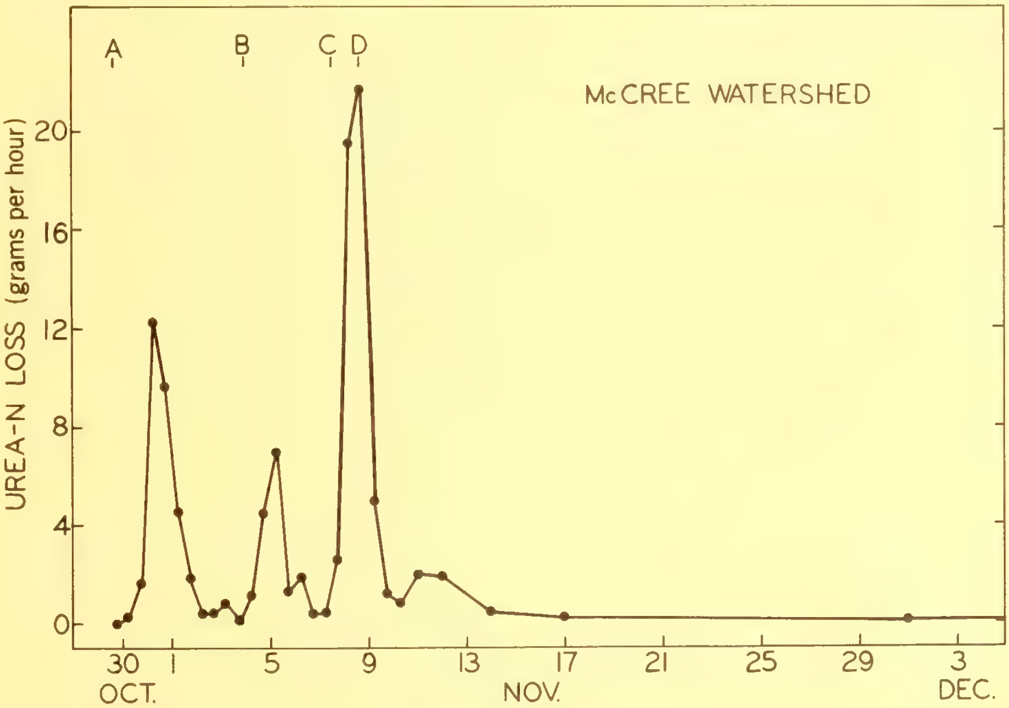
[2] Personal communication with D. G. Moore. Forest Sci. Lab., Pac. Northwest Forest & Range Exp. Sta., Corvallis, Oreg.

The three distinct periods of aerial fertilization activity on the McCree Creek watershed (October 30-31, November 4, and November 7-8) were evident in the stream water analysis. Each fertilization period was identified by a marked increase in urea-N as shown in figure 1. The maximum urea-N carried in the stream after each fertilization period was 12.25, 6.89, and 21.71 grams per hour (355, 185, and 616 parts per billion). The urea-N outflow rate dropped rapidly after the end of the third fertilization period (November 8) and became nondetectable on December 1. Streamflow during the period October 3 through December 31 ranged from 8.2 to 10.3 liters per second (0.29 to 0.36 cubic foot per second), with the exception of short duration peak flows of 17.3 liters per second on November 8

Figure 1.--*Streamflow urea-nitrogen loss from McCree Creek watershed after fertilization with 59.8 metric tons of urea.* A, B, *and* C, *three periods of fertilization;* D, *period of highest loss.*

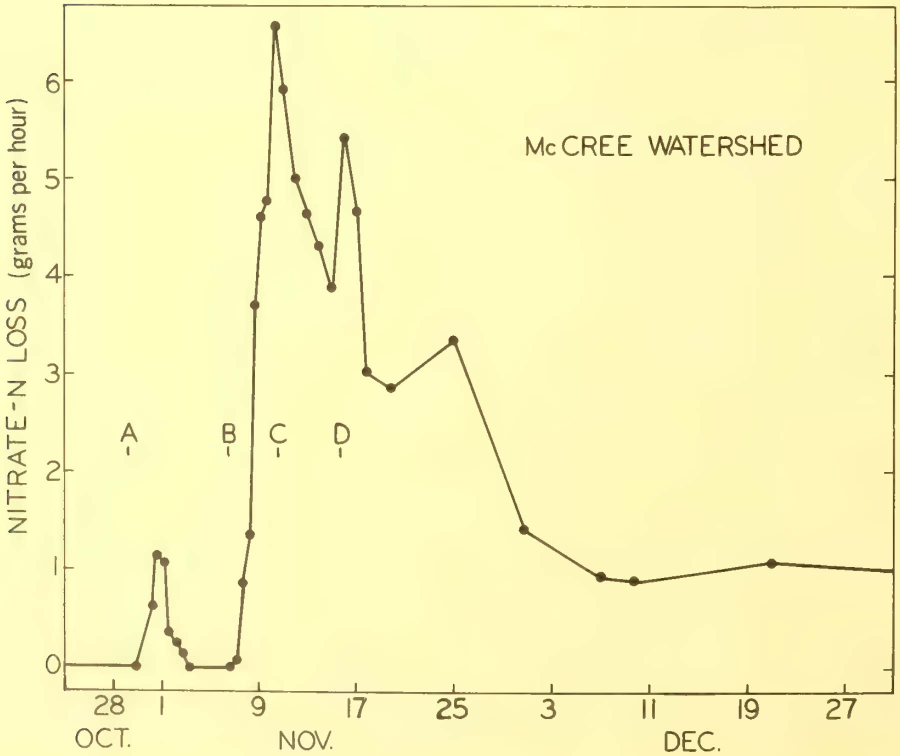


following a short period of heavy precipitation the evening of November 7 and 11.04 liters per second on November 16, again after a short period of rain. Flow rates returned to the average within 24 hours after these two peak flow rates. Total weight of urea-N transported by streamflow from the watershed during the period October 30 to December 1 was estimated at 1.37 kilograms.

No ammonia-N was measurable in McCree Creek during the sampling period. Minimum measurable level of ammonia-N was 0.2 parts per million.

After the first fertilization period on McCree Creek watershed October 30-31, the nitrate-N carried in the stream rose from nondetectable levels to a peak of 1.14 grams per hour (53 parts per billion concentrate). This peak was at 0900 hours, November 1 (fig. 2). Nitrate-N returned to nondetectable levels at 2100 hours, Novem-

Figure 2.--*Streamflow nitrate-nitrogen loss from McCree Creek watershed after fertilization with urea.* A *and* B, *first and third period of fertilization;* C, *period of highest loss; and* D, *secondary peak loss associated with precipitation activity.*



ber 3 and remained there until 2100 hours, November 7. The third and heaviest fertilization period was November 7-8. The level of nitrate-N transported by the stream again rose very rapidly and reached a maximum level of 6.56 grams per hour (210 parts per billion concentrate) at 2100 hours, November 10. High levels of nitrate were also recorded on November 16 after a short period of rain and on November 25. No reason for the high level on November 25 was observed. Nitrate-N streamflow levels decreased to a nearly constant 1 gram per hour after December 7, 1 month following fertilization. For the period October 31 to December 31, 2.90 kilograms of nitrate-N was estimated to have been carried by streamflow from the McCree Creek watershed.

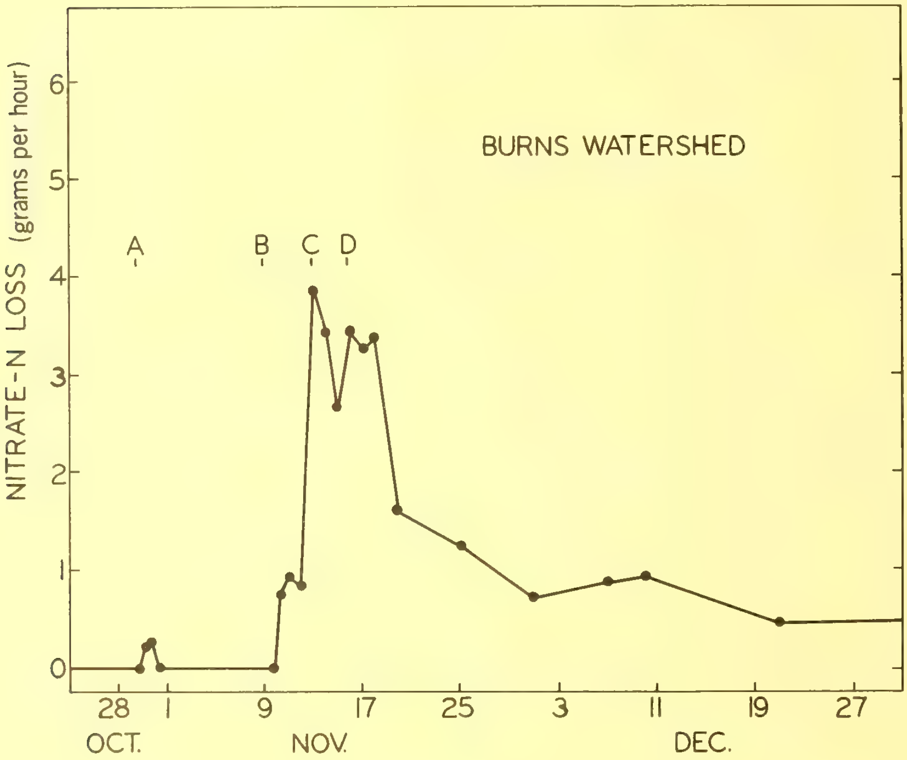
No ammonia-N (detection limit 0.2 parts per million) or urea-N was detected in the Burns Creek sampling. The load of debris in the stream channel was apparently sufficient to remove all of the ammonia-N. Associated with the first fertilization period on Burns Creek watershed October 30-31, nitrate-N transported by streamflow increased to a maximum level of 0.29 grams per hour (5 parts per billion) at 0900 hours, October 31 (fig. 3). Nitrate-N in the streamflow returned to nondetectable levels at 2100 hours, October 31 and remained there until 2100 hours, November 10. Associated with the second period of fertilization November 9-12, the nitrate-N increased to 3.86 grams per hour (68 parts per billion concentrate) on November 13. Streamflow during the period of October 30 to December 31 ranged from 13.9 to 17.5 liters per second (0.49 to 0.62 cubic foot per second). No large changes in streamflow volume were noted in Burns Creek during the observation period. For the period October 30 to December 31, 1.45 kilograms of nitrate-N was estimated to have been carried by streamflow from the Burns Creek watershed.

SUMMARY AND CONCLUSIONS

Nitrogen carried by streamflow was monitored for 60 days following the fertilization of two watersheds with urea and with ammonium sulfate at the rate of 55 kilograms of N per hectare. A third watershed was the unfertilized control. Small amounts of urea-N and nitrate-N found in water from the fertilized watersheds contrasted with none in the control stream. The highest concentration of nitrate-N measured was 210 parts per billion.

The urea appeared to be from fertilizer falling directly into the stream water. The reason for the rapid increase in nitrate-N concentration in the stream is unknown. The apparent conversion from urea and ammonium sulfate to nitrate-N as monitored in this study is much faster than that shown to occur in soils (McLaren 1970), particularly at 5° C. stream temperature. Future research is needed on this phenomenon.

Figure 3.--*Streamflow nitrate-nitrogen loss from Burns Creek watershed after fertilization with 157.9 metric tons of ammonium sulfate.* A *and* B, *first and second period of fertilization;* C, *period of highest loss; and* D, *secondary peak loss associated with precipitation activity.*



With the spring snowmelt and consequent increase in stream volume, additional nitrogen may be carried with sediments and lost from the watershed. A very small nitrogen loss from soil leaching is expected, particularly with the low soil nitrogen and high soil surface carbon levels following fire.

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USDA FOREST SERVICE RESEARCH NOTE

PNW-170 December 1971

EVALUATION OF R-55 AND MESTRANOL TO PROTECT DOUGLAS-FIR SEED FROM DEER MICE

by

Glenn L. Crouch, *Principal Plant Ecologist*
and
M. A. Radwan, *Principal Plant Physiologist*

ABSTRACT

Bioassays using deer mice showed that R-55, a thiocarbamate derivative, applied as 1- and 2-percent coatings was ineffective in reducing consumption of Douglas-fir seed. At 2 percent, mestranol, an antifertility chemical, reduced seed consumption to levels comparable with endrin applied at 0.5 percent without impairing germination.

Keywords: Seed treatment, mice, biological assay, pesticides.

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife -- if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

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INTRODUCTION

Losses of conifer seed to rodents have plagued reforestation efforts for many years, and much has been written about efforts to control these losses (Radwan 1970). In 1956, a chemical treatment based on endrin[1] was introduced to protect the seeds of many conifer species from seed-eating rodents (Anonymous 1956). However, present concern over pesticide hazards dictates that endrin, a persistent chlorinated hydrocarbon, be replaced as a seed protectant with a safer chemical.

Recent work in Canada indicated that R-55 (a thiocarbamate derivative produced by Phillips Petroleum Co.) effectively reduced consumption of white spruce (*Picea glauca*) seed by deer mice (*Peromyscus*) (Radvanyi 1970). About the same time, Howard and Marsh (1969) reported that mestranol (an antifertility chemical produced by Syntex Laboratories) was often poorly accepted by rats (*Rattus norvegicus*) and voles (*Microtus* spp.) suggesting that the compound might be useful as a rodent repellent for protecting conifer seed. In this study, therefore, we conducted trials with both R-55 and mestranol on Douglas-fir (*Pseudotsuga menziesii*), the major species seeded in the Pacific Northwest. Evaluations were based on laboratory bioassays using deer mice (*P. maniculatus*) as test animals and endrin as a chemical standard. Also, seeds of effective treatments were germinated to detect possible adverse effects of the chemicals employed.

MATERIALS AND METHODS

Seed treatment.--One seed lot of Douglas-fir from a low-elevation source in western Washington was used for all treatments. Seed, in 1/10-pound batches, was coated with each of the test chemicals using 4 milliliters (ml.) Dow Latex 512-R (diluted, 1 latex: 9 water by volume) as adhesive and 0.4 ml. DuPont Monastral Green GW 794 dye as coloring agent. In each case, seed was wet with a slurry of the test chemical in the adhesive-dye mixture, spread in a thin layer, and allowed to dry overnight under a hood at room temperature.

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[1] Mention of chemical companies and their products does not represent endorsement by the Forest Service or the U.S. Department of Agriculture.

Concentration percents of the active ingredients by weight were: 2 and 5 for R-55, 1 and 2 for mestranol, and 0.5 for endrin. The R-55 and mestranol powders were provided by Phillips Petroleum Company and Syntex Laboratories, Inc., respectively. Endrin was purchased as a 50-percent wettable powder (50-WP, Stauffer Chemical Co.).

Bioassays.--Deer mice live-trapped near Tumwater, Washington, in winter 1970-71, were used in all bioassays. Each trial was conducted with freshly caught mice which were brought to the laboratory, placed in individual cages, and supplied with water and a commercial pelleted ration until testing. One day prior to each trial, mice were offered a number of untreated Douglas-fir seeds equal to that subsequently used in the test. Animals not consuming at least 90 percent of the seeds were rejected from testing, and treatments were assigned at random to remaining mice. Seeds were offered in petri dishes, and water and food pellets were available *ad libitum* during each trial.

The number of mice per treatment, number of seeds offered each day, or duration of test was varied in each trial in order to evaluate the response of the animals to the treatments under several different conditions. In trial 1, 10 mice were offered 10 seeds per day for 5 consecutive days; in trial 2, five were given 25 seeds per day for 3 days; and in trial 3, five were fed 50 seeds per day for 3 days. Seed consumption was recorded daily, and the number of dead mice was noted each day during the trial and for 2 days after.

Germination.--Four 100-seed replicates were germinated on perlite at 24±1° C. after stratification for 21 days at 3° to 5° C., as prescribed in the standard test (Association of Official Seed Analysts 1965). Germinants were counted at weekly intervals and tests were run for 4 weeks.

Germinations of the seed coated with 2 percent mestranol, 0.5 percent endrin, and without treatment were determined. Seeds of other treatments were not germinated because the 1 percent mestranol was less effective in reducing consumption than the 2-percent treatment, and R-55 proved ineffective.

RESULTS AND DISCUSSION

Results of bioassays were similar in all trials (table 1). Consumption of seed was reduced markedly by treatment with endrin and mestranol but not by R-55. Animal mortality was low from all treatments. Feeding on seed treated with mestranol at 1 percent was not significantly different from that treated with R-55, 2 percent or 5 percent in trial 1, and therefore was not tested in trials 2 and 3. R-55 at 2 percent was similarly eliminated from subsequent tests. Untreated seed was not included as a treatment because many previous bioassays have shown that it was virtually always completely consumed (Radwan et al. 1970).

Average total germination percents over the 4-week period for seed coated with 0.5 percent endrin, 2 percent mestranol, and untreated were 81, 77, and 80, respectively, with no significant differences among treatments. Seed coatings with either endrin or mestranol did not affect seed viability. Germination of endrin-treated seed is in agreement with earlier data (Radwan et al. 1970), and the mestranol result shows that the chemical does not inhibit germination of Douglas-fir.

Laboratory results revealed no protective benefits from R-55 treatment of Douglas-fir seed using the method of seed treatment currently employed in the Pacific Northwest, and an established bioassay technique. In other tests not detailed here, mice were offered: (1) seed soaked in a solution of R-55 in dichloroethane similar to the dichloroethane-endrin treatment described by Radwan et al. (1970), and (2) untreated seed concurrently with seed treated with either R-55 or endrin. In both instances, R-55 had no effect whereas endrin markedly lowered seed consumption.

Our results contrast with those of Radvanyi (1970) who found that treating white spruce seed with R-55 greatly reduced its consumption. His seed species, method of seed treatment, and bioassay techniques were very different from those reported here, and the differences in findings could be related to any or all of these factors.

The promising results from mestranol justify continued research on it and similar compounds, although we clearly recognize that protective benefits shown in laboratory bioassays may not be attainable under field conditions. Moreover, the current high cost of mestranol might preclude its use even if the compound was proven effective and environmentally acceptable.

Table 1.--*Consumption of chemically treated Douglas-fir seed by deer mice and resulting animal mortality*

Treatment	Seed consumption		Animal mortality
	Mean number[1]	- - - - *Percent* - - - -	
TRIAL 1--10-ANIMAL, 10 SEEDS PER ANIMAL PER DAY, 5-DAY TEST			
R-55, 2 percent	49.6 a	99.2	0
R-55, 5 percent	49.5 a	99.0	0
Mestranol, 1 percent	37.5 ab	75.0	0
Mestranol, 2 percent	28.2 bc	56.4	0
Endrin, 0.5 percent	21.4 c	42.8	0
TRIAL 2--5-ANIMAL, 25 SEEDS PER ANIMAL PER DAY, 3-DAY TEST			
R-55, 5 percent	74.6 a	99.5	0
Mestranol, 2 percent	28.0 b	37.3	0
Endrin, 0.5 percent	24.8 b	33.1	0
TRIAL 3--5-ANIMAL, 50 SEEDS PER ANIMAL PER DAY, 3-DAY TEST			
R-55, 5 percent	147.6 a	98.4	0
Mestranol, 2 percent	64.8 b	43.2	0
Endrin, 0.5 percent	47.6 b	31.7	20

[1] Means followed by the same letter are not significantly different at the 5-percent level using Tukey's test (Snedecor 1961).

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USDA FOREST SERVICE RESEARCH NOTE

79: PNW-171

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MIDSUMMER FOLIAGE SPRAYS ON SALMONBERRY AND THIMBLEBERRY

by H. Gratkowski, *Research Forester*

ABSTRACT

Mixtures of picloram and phenoxy herbicide amines were compared with amitrole-T and low volatile esters of 2, 4, 5-T in midsummer foliage sprays on salmonberry (*Rubus spectabilis* Pursh) and thimbleberry (*Rubus parviflorus* Nutt.). Esters of 2, 4, 5-T were found to be the best herbicide for foliage sprays applied during late July in the Oregon Coast Ranges.

Keywords: Herbicides, spraying, brush control.

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Salmonberry (*Rubus spectabilis* Pursh) and thimbleberry (*Rubus parviflorus* Nutt.) are troublesome brush species on forest land in western Oregon and Washington. They are major components of most brushfields in the Coast Ranges and quickly occupy sites after logging or wildfires. One gallon of amitrole-T (2 lb. each of 3-amino-s-triazole and ammonium thiocyanate) per acre is generally applied as a foliage spray during early June to control salmonberry, but no herbicide gives long-term control of thimbleberry during that period. Foresters are seeking more effective herbicides and seasons of application for both species.

Finnis and Sund[1/] used a mixture of picloram (4-amino-3, 5, 6-trichloropicolinic acid) and phenoxyacetic herbicides[2/] to control salmonberry and concluded that such formulations show promise for chemical site preparation before planting nonstocked brushfields. This research note reports results from screening tests of two additional picloram-phenoxy herbicide mixtures as midsummer foliage sprays on salmonberry and thimbleberry. Control achieved with these mixtures is compared with that obtained using amitrole-T and low volatile esters of 2, 4, 5-T.

STUDY AREA AND METHODS

On July 22-23, 1966, two experimental formulations of picloram (M-2951 and M-3083[3/]) were applied as foliage sprays on 1/100-acre plots of salmonberry and thimbleberry in the Oregon Coast Ranges near Coos Bay, Oregon. M-2951 contained 1/2 lb. ae[4/] of picloram plus 2 lb. ae of 2, 4, 5-T per gallon, and M-3083 contained 1 lb. each of picloram, 2, 4-D, and 2, 4, 5-T per gallon in the form of triisopropanolamine salts. Amitrole-T and low volatile propylene glycol butyl ether esters of 2, 4, 5-T were applied on adjacent plots for comparison.

[1/] J. M. Finnis and Jimmie D. Sund. Planting of Douglas-fir seedlings following aerial application of Tordon 101 mixture herbicide. Down to Earth 26(1): 10-11, 1970.

[2/] 2, 4-D (2, 4-dichlorophenoxyacetic acid) and 2, 4, 5-T (2, 4, 5-trichlorophenoxyacetic acid).

[3/] Tordon formulations and 2, 4, 5-T were furnished by The Dow Chemical Company; amitrole-T was furnished by Amchem Products, Inc. Cooperation of both companies is sincerely appreciated.

[4/] Acid equivalent.

Tordon 10K pellets, 10 percent ae picloram as a potassium salt, were also tested on thimbleberry at rates of 10 and 30 lb. of pellets per acre. Pellets were distributed by hand; a 2-percent diesel oil-in-water emulsion was used as the carrier for 2, 4, 5-T; the other herbicides were applied in water carriers.

All sprays were applied with knapsack sprayers on replicated plots of salmonberry. Only one set of thimbleberry plots was treated. Response to treatment was evaluated at the end of the next growing season, 15 months later, using the Dow Rating System based on 10 observations per plot.

RESULTS AND DISCUSSION

Salmonberry

M-3083 at a rate of 1-1/2 gal. per acre produced a noticeably higher percentage of kill than any of the other treatments (table 1). This should be a useful treatment for controlling salmonberry in preparing nonstocked sites for reforestation with conifers. However, none of the picloram treatments would be useful for releasing young Douglas-firs from salmonberry. Young firs are damaged by picloram sprays.

Table 1.--*Effect of midsummer foliage sprays on salmonberry*

Herbicide	Treatment		Degree of control[1]
	Rate per acre	Carrier	
Amitrole-T	1 gal.	Water	2.4
Amitrole-T	1-1/2 gal.	Water	2.4
M-2951	1 gal.	Water	2.8
2,4,5-T	3 lb. ae	Emulsion	3.5
M-3083	1 gal.	Water	3.5
M-3083	1-1/2 gal.	Water	4.1

[1] A rating of 1.0 indicates little or no effect; a rating of 5.0 indicates complete kill with no resprouting.

Although 1 gal. of amitrole-T per acre is generally prescribed to release young Douglas-firs from salmonberry,[5] low volatile esters of 2, 4, 5-T appear far more preferable than either amitrole-T or picloram-phenoxy herbicide mixtures in midsummer foliage sprays. In this test, 3 lb. ae of 2, 4, 5-T killed a higher percentage of the salmonberry shrubs than either of the amitrole-T sprays and at a far lower cost than either amitrole-T or picloram mixtures. In contrast to picloram, neither amitrole-T nor 2, 4, 5-T damaged small Douglas-firs on the spray plots.

Thimbleberry

Low volatile esters of 2, 4, 5-T also were more effective than either amitrole-T or mixtures of picloram and phenoxyacetic amines in the midsummer foliage sprays on thimbleberry (table 2). Thimbleberry kill obtained with 2, 4, 5-T was good--almost equal to that obtained with 1-1/2 gal. of M-3083 per acre and far better than that obtained with amitrole-T. In addition, 2, 4, 5-T did not damage young Douglas-firs in the plot; M-3083 defoliated and damaged similar trees.

Table 2.--*Effect of midsummer foliage sprays and picloram pellets on thimbleberry*

Herbicide	Treatment		Degree of control[1]
	Rate per acre	Carrier	
Amitrole-T	1-1/2 gal.	Water	2
Tordon 10K[2]	10 lb.	None	2
Tordon 10K[2]	30 lb.	None	2
M-2951	1-1/2 gal.	Water	2
2,4,5-T	3 lb. ae	Emulsion	4
M-3083	1-1/2 gal.	Water	4.5

[1] A rating of 1.0 indicates little or no effect; a rating of 5.0 indicates all shrubs on the plot are dead.

[2] Picloram pellets distributed on soil surface.

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[5] P. G. Lauterbach. Chemical weeding and release of conifers in western Oregon and Washington. *In* Herbicides and Vegetation Management. Oreg. State Univ., Corvallis, Oreg., p. 148-151, 1967.

Where conifers are to be released from thimbleberry, low volatile esters of 2, 4, 5-T would be preferable to the mixture of picloram and phenoxy herbicides in M-3083. Even for site preparation in nonstocked brushfields, 2, 4, 5-T should provide as good control of thimbleberry at lower cost than possible with M-3083.

CONCLUSIONS

Although amitrole-T is generally considered better than 2, 4, 5-T for controlling salmonberry during the growing season, these limited tests indicate that there is a reversal in relative effectiveness of the two chemicals by midsummer. Low volatile esters of 2, 4, 5-T appear to be more effective than amitrole-T and less expensive than mixtures of picloram and phenoxy herbicide amines in midsummer foliage sprays to control salmonberry and thimbleberry.

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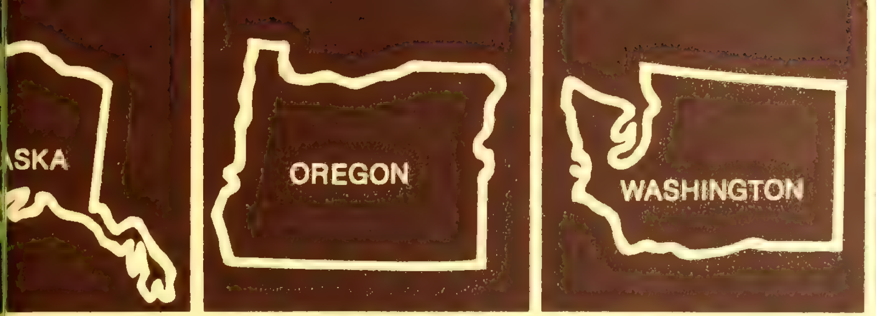

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USDA FOREST SERVICE RESEARCH NOTE

PNW-172 December 1971

THE EFFECT OF CATTLE AND BIG GAME GRAZING ON A PONDEROSA PINE PLANTATION

CLEMSON UNIVERSITY
AUG 17 1972
S.C. TECH. & AGR. DIV.

by

Paul J. Edgerton, *Wildlife Biologist*

ABSTRACT

Mixed conifer stands that have been clearcut, planted with trees, and seeded to grass are a potential source of summer forage for livestock and wildlife. Heights of planted trees in portions of a clearcut that had been ungrazed, grazed only by deer and elk, and by deer, elk, and cattle were compared. After five growing seasons, grazing had neither greatly harmed nor benefited growth and survival of the trees in the plantation.

Keywords: Grazing land, range management, forest clearcutting, ponderosa pine.

INTRODUCTION

The densely timbered mixed conifer forests of northeastern Oregon and southeastern Washington have long been considered important summer habitat for deer and elk but nearly unusable range for domestic livestock (Pickford and Reid 1948). However, in the last 10 years, timber harvests have drastically changed the forest environment. Many small stands have been clearcut, planted with trees, and seeded to grass to protect the disturbed soil. These sites are a potential source of summer forage for domestic livestock as well as wildlife while the new forest develops.

Presently, few clearcuts are grazed by livestock. Foresters are understandably reluctant to allow grazing before adequate management information is available to assure that grazing can be compatibly coordinated with the primary management goal--reforestation.

In 1965, a study of plant succession and animal use after logging was initiated in the mixed conifer forest type. One of the study sites was a clearcut that had been planted with young ponderosa pine (*Pinus ponderosa*)[1] and seeded to grass. It was one of the few areas grazed by cattle as well as deer and elk. To interpret the effects of combinations of use by these animals, we constructed a series of exclosures. This note reports the early growth and survival of the planted pines in those areas receiving different grazing use.

STUDY AREA AND METHODS

The study area was a 39-acre clearcut unit located approximately 12 miles west of Troy, Oregon, on the Umatilla National Forest. Elevation is 4,000 feet, and annual precipitation is estimated to be 30-40 inches, mainly from winter snows and spring and fall rains. Deep, well-drained soils have developed from wind-deposited volcanic ash. Adjacent unlogged stands are dominated by grand fir (*Abies grandis*), with lesser amounts of western larch (*Larix occidentalis*), Douglas-fir (*Pseudotsuga menziesii*), Engelmann spruce (*Picea engelmannii*), lodgepole pine (*Pinus contorta*), and occasional ponderosa pine. Measurements of height and age of the dominant grand fir indicate average site index class IV.[2] The understory is dominated by big huckleberry (*Vaccinium membranaceum*). Several other low shrubs, many shade-tolerant forbs, and occasional sedges and grasses are also present.

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[1] Sources for scientific nomenclature are Little (1953), Hitchcock et al. (1955), and Ingles (1965).

[2] Determined from site quality curves for Douglas-fir in McArdle, Meyer and Bruce (rev. 1961).

The area is summer range for big game and cattle. Moderate numbers of Rocky Mountain elk (*Cervus canadensis nelsoni*) and mule deer (*Odocoileus hemionus hemionus*), and a few white-tailed deer (*Odocoileus virginianus ochrourus*) are present from May through November. Cattle (cows and calves) are permitted to graze from early June through late July.

The unit was clearcut in 1963-64 which left cull logs and slash on the ground. In the fall of 1964, timothy (*Phleum pratense*) was seeded aerially at the rate of 0.5 pound per acre to quickly establish a ground cover on the highly disturbed soil. The following May (1965), 2-0 ponderosa pine nursery stock were hand planted at approximately a 10- by 10-foot spacing.

During the summer of 1965, 2-acre exclosures were constructed on gentle northwest- and southeast-facing slopes formed by the small drainage bisecting the unit. Deer and elk easily crossed the fences and used these areas, but cattle were excluded. Contiguous unfenced study sites were accessible to all grazing animals. Later, at the start of the 1966 grazing season, an adjacent portion of the southeast-facing slope was fenced from cattle, deer, and elk use.

In November 1967, 48 planted pines were selected for study in each of five grazing situations. Regularly spaced points were established along transects randomly located parallel to the slope contour. The tree nearest each point, regardless of size or apparent vigor, was tagged. At that time, the trees had been subject to grazing for three seasons. In November 1969, the end of the fifth season after planting, total height and damage due to needle browsing, bud breakage, trampling, and girdling were noted. When possible, causes of tree mortality were determined. The growth and survival of these trees will be followed through their 10th growing season and longer if warranted.

Supplemental information on animal use and foliage cover of competing shrubby and herbaceous plant species was estimated on permanently marked plots in August 1969. Cover was estimated by a method modified after that of Daubenmire (1959). Forage use was expressed as a percentage of the forage volume available before use.

RESULTS AND DISCUSSION

Survival of the pine plantation has been good. A survey by National Forest personnel in the spring of 1969 indicated that approximately 87 percent of the unit was satisfactorily stocked with at least 250 trees per acre.

A new ground cover has also developed rapidly. Foliage cover of major plant groups is summarized for 1969 in table 1. Seeded timothy has become well established throughout

Table 1.--*Foliage cover of major plant classes after five growing seasons in a mixed conifer clearcut grazed by deer, elk, and cattle*

Grazing treatment	Foliage cover				
	Grasses and grasslike	Forbs	Shrubs	Trees	Total[1]
	- - - - - - - - - *Percent* - - - - - - - - - - -				
No grazing	29	51	24	1	105
Deer and elk	26	38	16	2	82
Deer, elk, and cattle	20	43	14	1	78

[1] Cover of layered canopies of different species can total more than 100 percent.

the unit. Many seral species have also invaded the site. Abundant forbs include willowweeds (*Epilobium* spp.), mountain thermopsis (*Thermopsis montanus*), bull thistle (*Cirsium vulgare*), and Canada milkvetch (*Astragalus canadensis mortoni*). The most common shrub is sticky currant (*Ribes viscosissimum*).

Experience elsewhere (Baron 1962) suggests that successful establishment of the plantation could be attributed to the fact that pines, grass, and seral species began growth at the same time. One might speculate that survival and growth would have been poor if the trees had been planted after the ground cover had become well established.

The abundance and variety of forage available in the clearcut attracted both big game and cattle. Forage use by cattle was much greater than that by deer and elk. They grazed on all accessible palatable forage outside the exclosures. By the close of the grazing season, the appearance of the area grazed by cattle contrasted sharply with the area grazed by deer and elk (figs. 1 and 2).

Cattle grazed almost all species, but timothy was eaten by far the most frequently. Utilization of timothy varied greatly according to accessibility of the forage. Plants growing along skid trails and in other open areas were heavily used, and those growing through slash or adjacent to cull logs were lightly used. Access to a few small areas of forage was completely blocked by slash and logs.

Signs of the presence of deer and elk such as tracks, pellets, and beds were found frequently both inside and outside the cattle fences. However, forage use in the areas accessible only to big game was scattered and, when averaged, was relatively light. Canada milkvetch was most heavily used. Timothy was rarely eaten resulting in a dense layer of grass litter over the ground surface.

The planted pines were browsed lightly in each of the grazing situations. Nearly 30 percent of the pines showed evidence of browsing in 1967; 10 percent, in 1969. Usually only the tips of a few needles were clipped, but occasionally terminal buds were broken off causing laterals to assume dominance. The latter kind of damage was found most often along heavily traveled skid trails and resulted more frequently from trampling than browsing. Because of the heavy grass cover, some damage probably occurred while the cattle were grazing other plants.

Grazing damage was light because the grazing season was properly timed. By the time animals began to graze in late spring, an abundance of preferred herbaceous forage had already developed. Likewise, the cattle were removed by midsummer before forage was depleted or had become coarse and relatively unpalatable. Thus, they were not forced to graze less palatable vegetation, including the young pines.

Twenty-one (about 9 percent) of the 240 trees tagged died during the

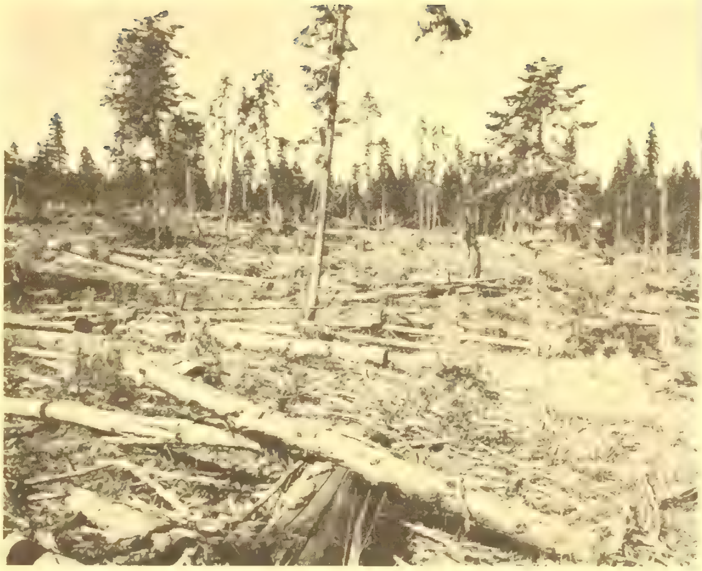

Figure 1.--A portion of the clearcut grazed by deer, elk, and cattle.

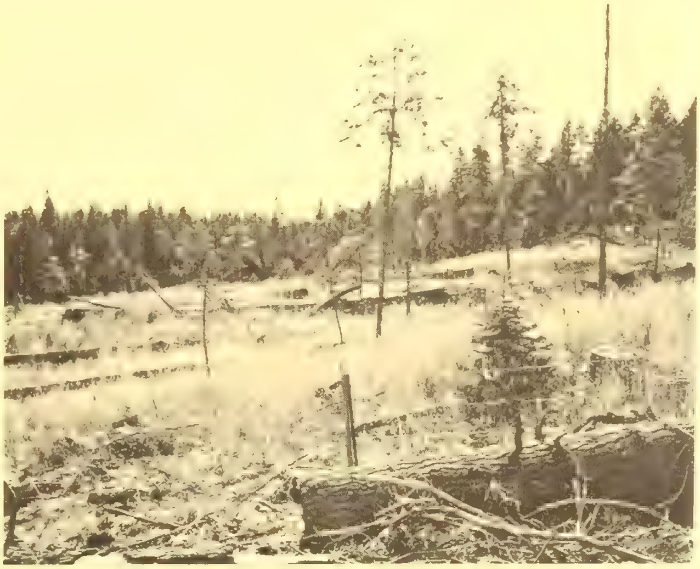

Figure 2.--A portion of the clearcut grazed only by deer and elk. Note the abundance of ungrazed timothy. This area adjoins the area shown in figure 1.

study period. Mortality was well distributed in the study area. Causes were trampling, 5 percent; porcupine (*Erithizon dorsatum*) girdling, 14 percent; gopher (*Thomomys* sp.) damage to the roots, 48 percent; and undetermined, 33 percent.

At the outset of the study, we anticipated that grazing a portion of the herbaceous vegetation might appreciably increase the availability of light, nutrients, and particularly, soil moisture for tree growth. Pearson (1942), Larson and Schubert (1969), and others have demonstrated that complete removal of herbaceous competition resulted in increased survival and growth of trees. Pearson (1942) also found that clipping competitive herbaceous species benefited growth of pine seedlings and suggested that grazing had possibilities as a silvicultural tool. In western Oregon, Hedrick and Keniston (1966) reported that carefully controlled grazing conserved soil moisture, thereby influencing the growth of planted Douglas-fir.

Despite this evidence, average tree heights (table 2) indicated that grazing had not greatly benefited growth of this plantation after five growing seasons. Perhaps competition for soil moisture was not a factor limiting growth either because of the high soil moisture retention and availability characteristic of deep volcanic ash soils (Pumphrey 1971) or because the trees were able to develop deeper root systems than the grass before the grass became well established.

The effects of grazing might have been more pronounced if the cull logs and slash had been piled or burned to

Table 2.--*Height of planted ponderosa pine after five growing seasons in a mixed conifer clearcut grazed by deer, elk, and cattle*

Grazing treatment	Number of trees measured	Average height	Standard error
		- - - - *Inches*	- - - -
No grazing	43	27.8	±1.2
Deer and elk	90	28.7	±0.9
Deer, elk, cattle	86	30.6	±1.0

allow more uniform grazing. Slash restricted movements of grazing animals and growth of forage. The variable pattern of use may have masked somewhat the benefits expected. Yet, in areas where grazing cannot be carefully controlled, slash could safeguard plantations against excessive trampling and browsing from overgrazing or improper season of use.

Grazing experiments by other investigators are underway in mixed conifer clearcuts in which the slash has been burned. Their results should yield additional information about relationships between slash disposal, pattern of grazing, and plantation damage.

Results of this study suggest that summer grazing by deer, elk, and cattle can be compatible with reforestation practices in mixed conifer clearcuts in northeastern Oregon and southeastern Washington. Under proper management, which gives due consideration to season of use and stocking rate, cattle prefer forage little used by deer and elk and otherwise wasted. Duration of the forage supply cannot yet be predicted, but studies in progress and being planned should provide information about the use of fertilizers and other forage plants to maximize forage production for both wildlife and cattle while the new forest develops.

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USDA FOREST SERVICE RESEARCH NOTE

PNW-173 January 1972

OCCURRENCE AND GENOTYPIC DIFFERENCES OF CHLOROGENIC ACID IN DOUGLAS-FIR FOLIAGE

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AUG 17 1972
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by

M. A. Radwan, *Principal Plant Physiologist*

ABSTRACT

Chlorogenic acid was identified in the foliage of Douglas-fir during the dormant season. Concentrations varied among genotypes and ranged between 75 and 390 p.p.m. in the fresh tissue.

Keywords: Plant physiology, Douglas-fir clones, chromatography, caffeoylquinic acid.

INTRODUCTION

Chlorogenic acid (3-0-caffeoylquinic acid) is one of the most widely distributed phenolic derivatives in plants (Hermann 1956, Buch 1960). Physiological studies have shown that the compound reacts synergistically with indoleacetic acid (Nitsch and Nitsch 1959) and undergoes changes in concentration with age (Koeppe et al. 1970) under the influence of various environmental factors (Zucker 1963, Koeppe et al. 1969) and during flower induction (Zucker et al. 1965). Further, other investigations have led to postulates of possible significant roles by chlorogenic acid in lignin synthesis (Stafford 1965), disease resistance (Farkas and Kiraly 1962), and allelopathic relations among plants (Koeppe et al. 1969). Because of these important effects and possible roles, lack of information on the occurrence of chlorogenic acid in conifers of the northern hemisphere, and our interest in

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phenolic compounds which may affect animal preferences for forest trees, Douglas-fir (*Pseudotsuga menziesii*) was chosen for study.

The present paper, therefore, describes the isolation and identification of chlorogenic acid from Douglas-fir foliage, and compares its concentration in four different genotypes grown at the same location.

MATERIALS AND METHODS

Plant material.--Foliage was obtained from 10-year-old, 15-foot-tall Douglas-fir trees grown at the Dennie Ahl Seed Orchard in western Washington. Four clones, SD-10, -13, -19, and -22, were used. Composite samples of about 300 grams each were collected from each clone during the dormant season (February-March) in 2 consecutive years, 1968 and 1969. Each sample was taken from 10 to 15 trees selected at random each year and consisted of 3-inch tips of secondary laterals at a height of about 5 feet up the trees. Reproductive buds were removed if present, and samples were individually sealed in glass containers and brought to the laboratory in a portable cooler.

Separation and identification.--Fresh plant material was chopped and 10-gram samples were defatted in petroleum ether (30-60° C.) and then extracted with 80 percent methanol for 24 hours in Soxhlet. The alcohol extract containing the phenolic compounds was evaporated *in vacuo* and the residue was taken up in 5 milliliters of 80 percent methanol for chromatography on Whatman No. 1 paper. Two dimensional chromatograms were developed with n-butanol:acetic acid:water, BAW, 4:1:5, upper phase (A), or BAW, 4:1:2.2 (B) in the first direction and 2 percent aqueous acetic acid, HOAc (C), in the second direction (Cartwright and Roberts 1954, Hergert 1960). Separations were also accomplished by one-dimensional chromatography on paper freshly washed with 5 percent methanol with solvent methyl-isobutylketone:formic acid:water, KFW, 14:3:2 (D) (Koeppe et al. 1969).

Chlorogenic acid was located on the chromatograms by its fluorescence under an ultraviolet lamp before and after fuming with ammonia (Hulme 1953), and colors were developed with several specific reagents (Roberts and Wood 1951, Swain 1953).

Identification of chlorogenic acid was made through comparison with authentic material by co-chromatography in four solvents, and spectral analysis (ultraviolet on methanol solutions and infrared on KBr pellets). Additional evidence was obtained by hydrolysis of the compound with alkali (2N NaOH for 2 hours under N_2 at room temperature) and with acid (2N HCl for 1 hour at 100° C.) followed by chromatographic separation and identification of the products (co-chromatography with authentic material in three solvents, examination under ultraviolet light, and reactions with spray reagents specific for each product (Roberts and Wood 1951, Cartwright and Roberts 1955, Reio 1958)).

Quantitative determination.--Spots, located under ultraviolet light without exposure to ammonia, were cut from the chromatograms and eluted with methanol. Chlorogenic acid in the solutions was determined spectrophotometrically at a wave length of 328 nanometers (nm) using appropriate blanks. Average concentrations in the tissues were calculated based upon two replicates with three chromatograms per replicate. Data were subjected to analysis of variance and means were separated according to Tukey's test (Snedecor 1961).

RESULTS AND DISCUSSION

Identification.--Comparison of the compound isolated from Douglas-fir foliage with authentic chlorogenic acid (CGA) showed that the two chemicals were identical in fluorescence, chromatographic behavior, spectrophotometric characteristics, and hydrolysis products. Thus, under ultraviolet light, the compound exhibited blue fluorescence which changed to green upon exposure to ammonia (Hulme 1953). Reactions with several spray reagents were also typical of CGA (Roberts and Wood 1951, Hulme 1953, Swain 1953). Co-chromatography with authentic CGA gave one spot in three solvents and a pair of spots for the *cis* and *trans* forms, characteristic of cinnamic acid derivatives, in 2 percent HOAc (Williams 1955). Average R_f values (from three papers) were: 0.60 (A); 0.64 (B); 0.54, 0.72 (C); and 0.49 (D). Absorption spectra were similar to those in the literature (Barnes et al. 1950, Hulme 1953, Haslam et al. 1964)--λmax. (70 percent methanol) = 328 nm with shoulders at 300, 233, and 216 nm; νmax. (KBr) = 1,260, 1,630, and 1,720 cm^{-1}. Further, both acid and alkaline hydrolyses yielded two spots as determined by chromatographic analysis of the products. The chromatographic behavior of these spots and their reactions with several spray reagents (Roberts and Wood 1951, Cartwright and Roberts 1955, Reio 1958) were identical with those of the known hydrolysis products of CGA--quinic and caffeic acids. R_f values of the acids were: 0.26 (A) and 0.89 (C) for quinic acid, and 0.79 (A) and 0.25, 0.61 (C) for caffeic acid.

Concentration.--Average concentration of CGA in the fresh foliage tissue (in p.p.m.) varied significantly ($P = 0.05$) among the four clones as follows: SD-10 = 170; SD-13 = 75; SD-19 = 390; and SD-22 = 113. On dry-weight basis, CGA concentrations (in milligrams per 100 grams of tissue) were: SD-10 = 39; SD-13 = 17; SD-19 = 91; and SD-22 = 26. These data indicate that Douglas-fir foliage contained low to moderate levels of CGA compared with other plant species (Sondheimer 1958).

Significance.--Chlorogenic acid is widely distributed in angiosperms. However, as far as is known, there are only two early reports of CGA in gymnosperms: *Podocarpus* and *Gnetum* (Hegnauer 1962). This study, therefore, reports, for the first time, the occurrence of CGA in the foliage of a northern-temperate conifer, Douglas-fir. Importance of this finding is not immediately apparent. However, the genotypic differences in CGA found here, and the reports mentioned above on important effects and possible roles of CGA in plants, suggest that additional work to explore relationships between differences in important characteristics (e.g., seed-producing ability, susceptibility to injury by various biota, etc.) of various families of Douglas-fir and their CGA content may be useful in tree breeding programs.

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USDA FOREST SERVICE RESEARCH NOTE

PNW-174 April 1972

FIRST-YEAR PERFORMANCE OF DOUGLAS-FIR AND NOBLE FIR OUTPLANTED IN LARGE CONTAINERS

by

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and

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AUG 17 1972
SCI., TECH. & AGR. DIV.

ABSTRACT

In early August, 1-1/2-year-old nursery-grown Douglas-fir and noble fir seedlings were potted into 10-inch-long cardboard and plastic mesh tubes, 7-inch-deep peat pots, and quart-size milk cartons. After growing several months outdoors, they were outplanted in fall or spring, along with bare-root 1-1's and 2-0's, on a site in the Oregon Cascades. First-year height growth of containerized trees averaged about 2-1/2 times greater than bare-root stock. Survival of all stock was relatively good but significantly higher for that in containers. Douglas-fir reacted differently than noble fir to transplanting while succulent and outplanting in fall or spring. Growth of all stock types will be measured for several years.

Keywords: Transplants, seedlings, container stock, seedling survival, seedling height growth, planting season, seedling succulence, transplant shock, Douglas-fir, *Pseudotsuga menziesii*, noble fir, *Abies procera*.

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INTRODUCTION

Several containerized regeneration systems have been developed in the last few years with heavy emphasis on mechanized production and planting.[1] But container planting must be proven biologically sound before it becomes a truly established reforestation technique. One test to determine its biological potential was begun in the Oregon Cascades in 1969. Survival and growth of 2-year-old Douglas-firs (*Pseudotsuga menziesii* (Mirb.) Franco) and noble firs (*Abies procera* Rehd.), outplanted in relatively large containers, were compared with results obtained by planting bare-root seedlings and transplants.

METHODS

In early August 1969, 1-1/2-year-old Douglas-fir and noble fir seedlings of appropriate seed sources were lifted from the U.S. Forest Service's Wind River Nursery near Carson, Wash. Most Douglas-firs were succulent and in a second flush of growth; the noble firs appeared less succulent, and many had set bud. Lifted seedlings were packed immediately in moist sphagnum moss, transported to Corvallis, Oreg., in portable coolers, and held in cool storage until potted by hand during the following week.

Following grading, 250 seedlings of each species were randomly allocated and potted individually into each of four types of containers (fig. 1):

1. Milk carton--polyethylene-covered cardboard, 1-quart size, 3 inches square and 9 inches deep, with drainage holes in bottom.

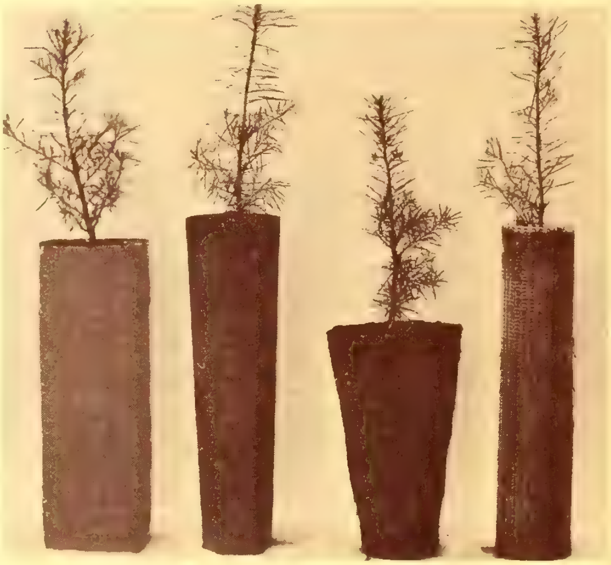

Figure 1.--Douglas-firs 2 months after potting in, left to right, milk carton, Weyerhaeuser tube, Fertil pot, and Conwed tube.

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[1] *Kinghorn, J. M. The status of container planting in western Canada. For. Chron. 46: 466-469. 1970.*

MacKinnon, George E. Container planting in Ontario. For. Chron. 46: 470-472, illus., 1970.

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2. Weyerhaeuser tube[2/]--resin-impregnated cardboard, 2-1/2 inches in diameter at the top and 10 inches deep, slightly tapered, with 1/8-inch holes in bottom and lower third of cylinder.

3. Fertil pot--pressed peat and paper fiber, 4 inches top diameter, 2 inches bottom diameter, and 7 inches deep.

4. Conwed tube--stiff plastic mesh, 2 inches in diameter and 10 inches deep, with cheesecloth covering the bottom opening.

Potting soil was a mixture of three parts sandy loam to one part peat moss, by volume.

Additional seedlings of each species were transplanted into 10-inch-deep flats filled with the same soil mixture; these transplants were prepared for use as nominal 1-1's. A second bare-root treatment consisted of seedlings left growing in the nursery until outplanted as 2-0's.

Both potted and transplanted seedlings were placed in coldframes at Corvallis and kept shaded and watered through the remainder of the 1969 growing season. They were sprinkled with Shive's nutrient solution during September. In late October, just before the first outplanting, ammonium sulfate fertilizer was lightly applied to seedlings in all pots and flats in an effort to correct slight foliage chlorosis. Meanwhile, seedlings left undisturbed at Wind River Nursery had been watered and fertilized routinely.

Potted and bare-root trees were outplanted on two clearcuts located within one-half mile of each other in the Whitewater Creek drainage, Willamette National Forest, near Detroit, Oreg. The study areas are on north-facing slopes on the west side of the Cascades; elevations range from 3,500 to 4,000 feet above sea level. Both areas were logged and broadcast burned in 1968. The sites are not considered severe.

Douglas-fir and noble fir were planted separately in four blocks each, two in each clearcut. Each block contained 12 rows, each row designated at random to be planted in the fall or spring with one of the six types of stock. Rows spaced 9 feet apart crossed the contours, and trees were planted 9 feet apart within each row. Planting of 25 trees per row was planned, but the actual number varied from nine to 25, depending upon the quantity of plantable trees available. Thus, total number of trees planted for different types of stock ranged from 163 to 200 for Douglas-fir and from 107 to 144 for noble fir.

[2/] *The identification and description of commercial products in this publication are solely for information purposes. Endorsement of any commercial product is not intended.*

Half of each type of stock was planted in late October 1969 by a Ranger District crew using long, narrow spades. Containers were inserted intact except that bottoms of milk cartons were removed to permit root emergence. Most cheesecloth bottoms on Conwed tubes had either fallen or rotted off, and cloth remaining was not considered a hindrance to root growth.

Remaining trees overwintered in coldframes at Corvallis and in seedbeds at Wind River Nursery. The trees at Corvallis were treated with 6-10-4 fertilizer in mid-March at a rate equivalent to 50 pounds nitrogen per acre. Almost all trees overwintering at Corvallis burst bud in early April and were in succulent condition when outplanted as soon as snow melted in late May 1970. Those from the nursery had tight buds; they had been lifted about 10 days before planting and placed in cold storage.

Survival counts and height growth measurements were made in late September 1970. Summarized data were analyzed for each species by analysis of variance methods appropriate for a randomized block design with treatments arranged in a 2 x 6 factorial. The container effects were isolated in a set of orthogonal contrasts. Standard statistical procedures were used to adjust for the unequal number of trees initially planted per treatment.

RESULTS

PERFORMANCE IN COLDFRAMES

Even though transplanted during the growing season, Douglas-fir recovered quickly and apparently suffered little damage. Most noble firs, on the other hand, began to lose needles the second and third weeks after potting. Some of these eventually died, but many burst bud in the spring and were outplanted.

Losses occurred in the coldframes during winter, causing a reduction of plantable Douglas-fir and a further reduction of plantable noble fir. They were lowest in flats and milk cartons and highest in Fertil pots--38-percent mortality of Douglas-firs and 50-percent of noble firs.

PERFORMANCE AFTER OUTPLANTING

First-season survival of containerized Douglas-fir averaged 95 percent compared with 83 percent for bare-root stock (table 1). Comparable averages for noble fir were 88 percent for containerized trees and 78 percent for bare-root stock (table 2). For each species, the difference in average survival was statistically significant.3/

Survival of Douglas-fir did not differ significantly among containers

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3/ Unless otherwise stated, statistical significance is at the 99-percent level of probability.

Table 1.--*First-season survival of Douglas-fir*

Container or stock type	Average survival for each type of stock					
	Fall planting		Spring planting		Both plantings	
	Percent[1/]					
Milk carton	87.5	(98)	97.0	(100)	92.2	(198)
Weyerhaeuser tube	97.8	(96)	98.8	(81)	98.3	(177)
Fertil pot	92.9	(100)	98.3	(63)	95.6	(163)
Conwed tube	89.8	(99)	96.2	(79)	93.0	(178)
Container average	92.0	(393)	97.6	(323)	94.8	(716)
1-1 transplant	82.8	(97)	85.2	(95)	84.0	(192)
2-0 seedling	78.5	(100)	87.0	(100)	82.8	(200)
Bare-root average	80.6	(197)	86.1	(195)	83.4	(392)
Average for all stock	88.2		93.8		91.0	

[1/] Number of trees planted are listed in parentheses.

or between bare-root seedlings and transplants. Among containerized noble fir, survival differed significantly only for those outplanted in the fall in milk cartons, averaging 77 percent compared with 91 percent for those in other containers. Survival of noble fir transplants averaged 85 percent, significantly greater than the 70 percent for 2-0 seedlings. The difference was mostly due to very high survival of fall-planted transplants.

Survival of spring-planted Douglas-fir averaged 94 percent, significantly better than the 88-percent average for those planted in the fall. The difference in average survival between fall and spring plantings of noble fir was not significant.

Height growth of containerized Douglas-fir averaged 8.1 cm., significantly greater than the 2.8-cm. average for bare-root stock (table 3). Trees in the Conwed tubes grew fastest, followed by those in Fertil pots, Weyerhaeuser tubes, and milk cartons. Trees in the tubes and pots grew significantly taller than those in milk cartons. The difference in average

Table 2.--*First-season survival of noble fir*

Container or stock type	Average survival for each type of stock					
	Fall planting		Spring planting		Both plantings	
	Percent[1]					
Milk carton	77.1	(72)	93.0	(72)	85.0	(144)
Weyerhaeuser tube	90.0	(71)	91.6	(72)	90.8	(143)
Fertil pot	95.5	(71)	86.1	(36)	90.8	(107)
Conwed tube	86.1	(72)	87.5	(72)	86.8	(144)
Container average	87.2	(286)	89.6	(252)	88.4	(538)
1-1 transplant	97.3	(73)	73.5	(71)	85.4	(144)
2-0 seedling	71.9	(71)	69.0	(71)	70.4	(142)
Bare-root average	84.6	(144)	71.2	(142)	77.9	(286)
Average for all stock	86.3		83.4		84.9	

[1] Number of trees planted are listed in parentheses.

height growth between bare-root seedlings and transplants was not significant.

Height growth of containerized noble fir averaged 5.1 cm., significantly greater than the 2.1-cm. average for noble fir planted bare-root (table 3). This species grew fastest in Fertil pots, followed by Weyerhaeuser tubes, Conwed tubes, and milk cartons. Height growth differences between trees in the four types of containers were all significant. Height growth of bare-root transplants, 2.3 cm., averaged slightly but significantly better than the 1.8 cm. for bare-root seedlings (95-percent level of probability).

Height growth of spring-planted Douglas-fir, 7.1 cm., was significantly greater than the 5.6 cm. average for those planted in fall. There was only one exception to this general trend--in Fertil pots, fall-planted Douglas-firs grew more than those planted in the spring. In fact, they had the most growth of any fall-planted stock but averaged next to lowest among spring-planted, containerized Douglas-firs. Fall-planted noble fir

Table 3.--*First-season height growth of Douglas-fir and noble fir after outplanting in the fall or spring*

Container or stock type	Average height growth for each type of stock					
	Douglas-fir			Noble fir		
	Fall	Spring	Both seasons	Fall	Spring	Both seasons
	Centimeters					
Milk carton	6.0	6.8	6.4	5.0	3.5	4.2
Weyerhaeuser tube	6.5	10.3	8.4	6.2	4.6	5.4
Fertil pot	9.4	7.7	8.6	7.0	5.6	6.3
Conwed tube	7.1	11.1	9.1	5.4	3.7	4.6
Container average	7.2	9.0	8.1	5.9	4.4	5.1
1-1 transplant	2.2	3.3	2.8	2.5	2.1	2.3
2-0 seedling	2.6	3.2	2.9	1.9	1.8	1.8
Bare-root average	2.4	3.2	2.8	2.2	2.0	2.1
Average for all stock	5.6	7.1	6.4	4.7	3.6	4.1

averaged 4.7 cm. in height growth, significantly taller than the 3.6-cm. average for those planted in spring. Better growth of fall-planted noble fir was consistent throughout all container and bare-root stock types.

In addition to higher survival and faster growth, general appearance of containerized stock was superior to that of bare-root trees (fig. 2). Containerized trees of both species were stockier and branched more.

DISCUSSION

Two prime considerations influenced design of this study: (1) test the largest containers that might reasonably be used in western reforestation, and (2) determine biological potential of the containerized trees before becoming concerned with production mechanics. Increased survival and a two- to three-fold increase in first-season height growth on a favorable site clearly indicate that nursery

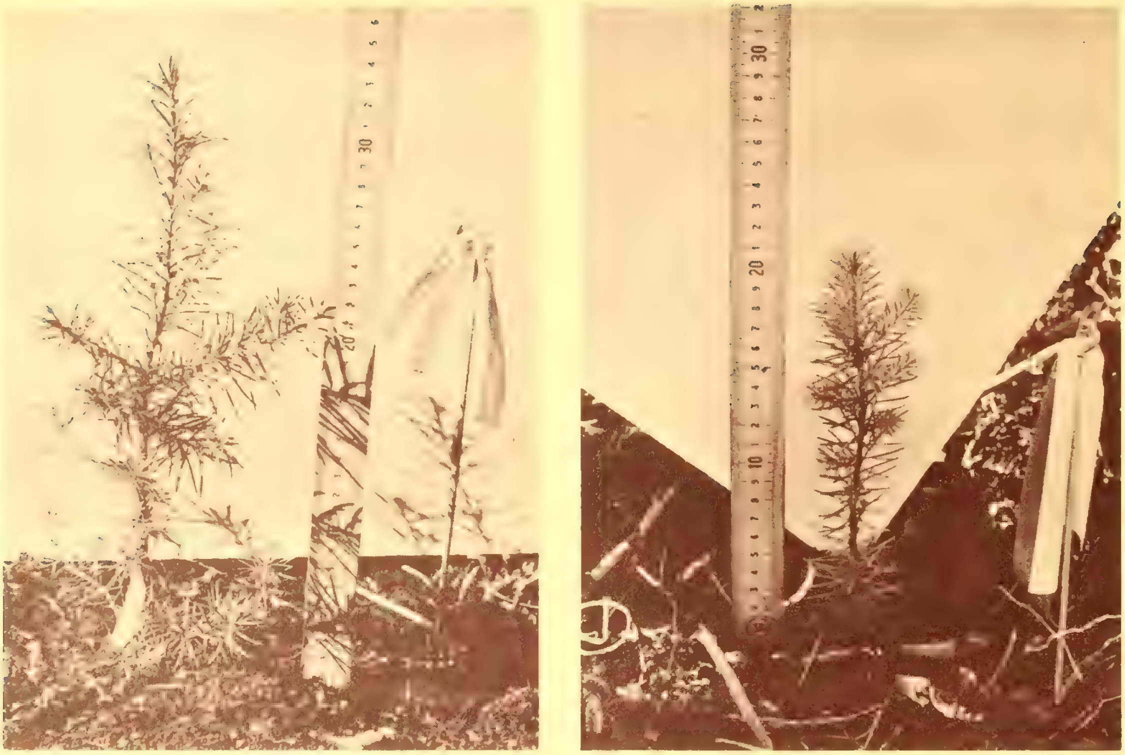

Figure 2.--Douglas-fir in Conwed tube (left) and bare-root (right) after the first growing season.

stock benefited from a conditioning period in containers. The biological effect might result from tree development during the conditioning period, from protection the container provides during transport and handling of the tree, from better soil moisture or nutrient conditions while roots become established, or from a combination of these factors. Differences in performance of bare-root and containerized trees might be accentuated even more on severe sites or in large-scale operations where bare-root stock does not receive the intensive care or careful planting it received in this study.

It could be argued that the improved performance of containerized stock is not due to the container and attendant intensive care but to the double culling such stock received. This possibility exists, but several pieces of evidence counter such interpretation: (1) all types of stock were culled to favor use of the sturdiest, healthiest trees available; (2) transplants received the same fertilization, watering, and double culling but did not match performance of containerized trees; and (3) in Fertil pots--the container with the highest wintertime tree losses--growth of spring-planted Douglas-firs was less than for those planted in the fall. Since the opposite was true for the five types of stock with less loss (culling), improved field performance can hardly be attributed to heavy culling.

During conditioning in the coldframes, trees were damaged by or died from two primary causes--transplant shock and late winter drought caused by insufficient watering during drying winds. Trees on exposed edges were damaged most. Field performance of containerized trees might have been even better if it had not been necessary to outplant many stressed and sparse-needled trees. With some change in future procedures, both causes of damage and mortality can readily be avoided.

Generally accepted planting instructions include the admonition that planting stock should be hardened off before lifting and outplanting. This precept was violated twice--first to launch the study in early August and, second, in delayed spring planting caused by lingering snow--with interesting consequences. Succulent Douglas-firs that were transplanted in early August and outplanted in late October survived and grew as well as 2-0 seedlings which hardened off at the nursery. Despite loss of needles, noble firs that were transplanted in August and outplanted in October survived and grew faster than the seedlings straight from the nursery. However, some noble fir transplants were culled prior to fall outplanting. Transplants of both species, outplanted after their buds burst in the spring, equaled or bettered survival and growth of 2-0 seedlings whose buds were still tight. These results indicate that greater flexibility in transplanting and outplanting than now practiced is feasible if the biological limitations of succulent seedlings are adequately determined.

Differences in survival and height growth arising from fall or spring planting of Douglas-fir and noble fir merit scrutiny. Survival and growth of spring-planted Douglas-fir averaged significantly better than for fall-planted Douglas-fir. Though sometimes minor, the planting season differences were consistent for seedlings, transplants, and containerized trees with one exception--in Fertil pots, fall-planted Douglas-firs grew more than those planted in the spring. This exception can probably be discounted because trees in Fertil pots dried out more over winter in the coldframes than any others. Thus, study results were consistent with the general operational experience that spring-planted Douglas-fir does best.

Unexpectedly, noble fir performance was substantially different. Height growth of fall-planted stock was significantly better and survival of fall- and spring-planted trees did not differ significantly. Two different explanations seem plausible: (1) perhaps this species cannot tolerate spring outplanting in a growing, succulent condition as well as Douglas-fir can, or (2) fall planting is intrinsically more favorable for noble fir. Future investigations to learn more about noble fir's nursery conditioning and its subsequent growth responses seem important.

Periodic remeasurement during the next few years should reveal how long these containerized trees sustain their initially faster height growth. Differences between containers may also become more pronounced, particularly if some containers impede root development. Milk cartons, the bulkiest and hence the most difficult containers to transport and plant, already appear less favorable for tree survival and growth than the other three types.

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USDA FOREST SERVICE RESEARCH NOTE

PNW-175

May 1972

THE SEED ORCHARD TREE AS A POLLEN SAMPLER:

A MODEL AND EXAMPLE

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by

Frank C. Sorensen, *Principal Plant Geneticist*

ABSTRACT

A model is developed which uses the seed tree as a pollen sampler and attempts to partition the pollen it receives into self pollen, pollen from immediately surrounding neighbors, pollen from slightly more distant neighbors, and background pollen. An example, using data from several sources, is introduced to illustrate the use of the model.

KEYWORDS: Pollen dissemination, seed orchards, Douglas-fir.

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INTRODUCTION

Discovery of two Douglas-fir trees with an albino single-gene marker at the same chromosomal locus has provided a means to sample distribution patterns of pollen in Northwest seed orchards. The method involves grafting scions of the trees into the orchards in patterns permitting detection of their cross pollination at various distances and relating this to total seed yield of the sample tree. To utilize this possibility requires development of both the layout patterns of such grafts in an orchard and a mathematical model that would interpret results in terms of the most important questions from such sampling. A mathematical model developed for the simplest assumptions that appear to partition total pollen into these classes is presented in this paper.

Source of pollen falling onto female strobili of trees may be arbitrarily divided into four categories: (1) that coming from the tree itself, (2) that coming from the immediate neighboring trees or trees within about 50 feet, (3) that from trees 50 to several hundred feet away, and (4) that from further away, or what will be called here "background pollen." In the seed orchard, the last three categories may be thought of as "near-neighbor," "other-orchard," and "nonorchard" pollens.

The movement of objects which are wind dispersed in nature has usually been reported in the form of frequency-distance curves proceeding away from the source of the object (Colwell 1951, Silen 1962, Strand 1957, Wang, Perry, and Johnson 1960, and Wright 1952 for conifer pollen; Bateman 1947a and 1947b, Hodgson 1949, and Meinders and Jones 1950 for agricultural crop pollen; and Dahms 1963, Fowells and Schubert 1956, Roe 1967, Shearer 1960, and Yocom 1968 for coniferous seeds of various sizes). Almost always the curves associated with the deposition of wind-distributed objects have been curvilinear and show the great majority of the objects to be deposited near the source. In the case of pollen, this has led to the calculation of mostly small- to moderate-sized neighborhoods[1/] (Wang, Perry, and Johnson 1960, Wright 1962) or to the conclusion that most pollination is by near neighbors (Colwell 1951, Ehrlich and Raven 1969, Langner 1953, and Strand 1957).

On the other hand, there have also been observations that much pollen goes up rather than down, that this pollen ("background pollen") may travel long distances before it is deposited, and that it

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[1/] Neighborhood refers to a group of trees. Small- to moderate-sized indicates a group of 10 to 300 trees, which at most orchard spacings would include trees in categories (2) immediate neighboring trees, and (3) trees 50 to several hundred feet away.

may contribute considerably to local pollen loads (Koski 1970, Sarvas 1967, Silen 1962, and Squillace 1967). Silen (1962) rationalized the two viewpoints by showing his distribution curve partitioned into a curvilinear portion from the sampled tree plus a highly uniform count of pollen from distant sources.

Part of this conflict in observation or interpretation may be due to different pollen sampling methods; part may be due to real differences in pollen dispersal under varied stand conditions. It is also thought that part of the difficulty may be a tendency to view pollen dispersal in terms of its distribution away from a source. Pollen sampling, by its very nature, emphasizes this view of the distribution pattern. In this note attention is focused on the pollen receptor (rather than on the pollen source) and on distribution toward the receptor (rather than away from the source). A model has been developed which treats the seed tree as a pollen sampler and then attempts to apportion the pollen catch among the various sources of the pollen. An example based on the model is also presented, and some of the assumptions associated with the example are discussed.

MODEL AND EXAMPLE

The model, which relates directly to pollen-frequency curves of the type cited above, is described in table 1 where it is applied to a seed orchard situation. In a general way, it could also be applied to natural stands, but their irregularity of spacing and age makes them harder to analyze than seed orchards. Assumptions associated with the model are given and discussed in table 2.

Although the model is simple in concept, because of the array of symbols it is rather difficult to decipher. Readers who are not interested in the fine points of pollen dispersion may wish to omit table 1 and go directly to the example (table 3).

Table 3 is meant to be as representative as possible of a Douglas-fir orchard of seed-producing age. Estimates of the relative amount of pollen contributed by the sample tree itself and the first nine ranks[2] of trees surrounding it (table 3) were read from a plot of the data given in table 1 of Wang, Perry, and Johnson (1960) for slash pine.[3]

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[2] See footnote 1, table 1.

[3] The pollen dispersal curve for slash pine was used because it was based on a tree of producing seed orchard size growing within its natural range. This is not meant to imply that Douglas-fir pollen and slash pine pollen would have the same dispersal properties. However, among the pollen dispersal curves given in the literature, this one seemed to be the most suitable because of tree size and because the tree was growing within the species range. The available pollen curves for Douglas-fir were either from much larger trees (which had, however, pollen dispersal curves of the same form as the curve for slash pine) or from trees growing outside the natural range.

Table 1.--*General model for partitioning the pollen received by any seed tree in a producing orchard*

(see table 2 for assumptions for model)

Rank1/	Distance2/	Pollen frequency3/	Relative pollen frequency	Fraction of pollen passing4/	Amount of pollen received, self pollen included		Amount of pollen received, self pollen excluded	
					Calculated	Percent	Calculated	Percent
Self5/	0	f_s	f_s/f_s	1	$\frac{f_s}{f_s}$	$\frac{1}{T}$		
1	d_1	f_1	f_1/f_s	1	$\frac{f_1}{f_s}$	$\frac{f_1}{f_s T}$	$\frac{f_1}{f_s}$	$\frac{f_1}{f_s(T-1)}$
2	d_2	f_2	f_2/f_s	p	$\frac{f_2 p}{f_s}$	$\frac{f_2 p}{f_s T}$	$\frac{f_2 p}{f_s}$	$\frac{f_2 p}{f_s(T-1)}$
3	d_3	f_3	f_3/f_s	p^2	$\frac{f_3 p^2}{f_s}$	$\frac{f_3 p^2}{f_s T}$	$\frac{f_3 p^2}{f_s}$	$\frac{f_3 p^2}{f_s(T-1)}$
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
n	d_n	f_n	f_n/f_s	p^{n-1}	$\frac{f_n p^{n-1}}{f_s}$	$\frac{f_n p^{n-1}}{f_s T}$	$\frac{f_n p^{n-1}}{f_s}$	$\frac{f_n p^{n-1}}{f_s(T-1)}$
Background					$\frac{b}{f_s}$	$\frac{b}{T}$	$\frac{b}{f_s}$	$\frac{b}{(T-1)}$
Total					T	100	T-1	100

1/ Rank refers to the "rings" of trees which surround the sample tree. In a regularly spaced orchard there will be 8 trees in the first rank. The next surrounding ring will contain 16 trees and is designated here as rank 2. The remaining ranks are analogous.

2/ Distance is used in reading pollen frequency from frequency-distance curve but is not used in calculations.

3/ To be read from frequency-distance curve.

4/ Fraction of pollen which passes through the ranks of trees intervening between the pollen source and the seed tree. See assumption 4, table 2, for further explanation.

5/ Sample or seed tree itself.

Table 2.--*Assumptions for model in table 1*

1. Sample tree is in an evenly spaced orchard.
2. All trees in each rank[1/] of trees are assumed to be equidistant from the sample tree. The distance used is the average distance between that rank and the sample tree.
3. If only pollen release is considered and the effect of distance is neglected, the pollen which the sample tree receives from itself (self pollen) is assumed equal to the pollen received from all trees within any one rank. The reason for this can be seen if one assumes rings of trees surrounding a sample, or target, tree with all trees of equal size and crowns touching. Then, assume the pollen travels in straight horizontal lines. At any one time the pollen that is released from the ring and travels toward the target comes from the equivalent of a single tree, no matter how large the ring. At the same time, and no matter what the direction of the wind, the sample tree will be contributing pollen to itself. In other words, it participates with all surrounding trees.
4. A portion of the pollen coming from second and subsequent ranks of trees surrounding the sample tree is sequentially intercepted or filtered out by intervening ranks. When a row of trees is standing between the pollen tree and the sample tree, it is going to capture or cause the loss of some of the pollen which is moving from more distant trees to the sample tree. In the model it is assumed that the same proportion of the incoming pollen is intercepted or otherwise diverted by each intervening row of trees.
5. The same proportion of trees in each rank produces pollen.
6. Producing trees yield pollen in equal quantities.
7. Time curves for pollen release are the same for all trees inside and outside the orchard.
8. Female flower receptivity and pollen shed are synchronous.
9. All pollen except self pollen is equally effective in producing seedlings. (The role of self pollen will be noted again in the discussion.)

[1/] See footnote 1, table 1.

Table 3.--*Proportions of pollen received by any seed orchard tree from surrounding orchard and nonorchard trees.*

Example is for a hypothetical Douglas-fir orchard

Rank[1]	Distance[2] (feet)	Pollen frequency[3]	Relative pollen frequency	Fraction of pollen passing[4]	Amount of pollen received, self pollen included		Amount of pollen received, self pollen excluded	
					Calculated	Percent	Calculated	Percent
Self	0	327	1.0	1	1.000	52.7	--	--
1	30	151	.462	1	.462	24.4	0.462	51.7
2	58	81	.248	1/2	.124	6.6	.124	13.9
3	87	50	.153	$(1/2)^2$	.038	2.0	.038	4.3
4	115	35	.107	$(1/2)^3$	.013	.7	.013	1.5
5	144	26	.080	$(1/2)^4$	.005	.3	.005	.6
6	172	20	.061	$(1/2)^5$	.001	.1	.001	.1
7	200	16	.049	$(1/2)^6$	(<.001)	(<.1)	(<.001)	(<.1)
8	229	13	.040	$(1/2)^7$	(<.001)	(<.1)	(<.001)	(<.1)
9	257	11	.034	$(1/2)^8$	(<.001)	(<.1)	(<.001)	(<.1)
Background					[5] .250	13.2	.250	27.9
Total					1.893		.893	

[1] See footnote 1, table 1.

[2] Average distance between sample tree and surrounding ranks when orchard spacing is 25 feet.

[3] From a hand plot of data in table 1 in Wang, Perry, and Johnson (1960).

[4] Fraction of pollen which passes through the ranks of trees intervening between the pollen source and the seed tree. In this example it is assumed that one-half of the incoming pollen is intercepted by each intervening row of trees.

[5] Background pollen = 0.25 x self pollen frequency; 0.25 averaged from figures 6 and 7 of Silen (1962).

Level of background pollen was estimated from figures 6 and 7 in Silen (1962). A seed orchard spacing of 25 feet was used in the example. Trees in the first two surrounding ranks were considered to be near-neighbors.

Table 3 estimates the relative contribution of various pollen sources when self pollen is included or excluded. In the case of Douglas-fir, which usually has a low self fertility (Sorensen 1971), the self pollen will probably not sire more than 5 to 10 percent of the viable seeds.[4/] Consequently, the best picture of seedling parentage should be obtained from the column where self pollen is omitted. In this hypothetical example, approximately 65 percent of the seeds were sired by pollen from the first two surrounding ranks of trees (near-neighbors), about 5 percent by other trees in the orchard, and about 30 percent by the background pollen.

DISCUSSION

The main purpose of the model is to provide a basis for numerically relating the contribution of various pollen sources. Because the frequency-distance curves are almost always characterized by high pollen frequency near the source and a rapid decrease in frequency with distance, the model offers the additional advantage of being moderately stable, even when the other assumptions are altered considerably. Perhaps this can best be seen by making changes in some assumptions and examining the effect on the example.

1. Form of the frequency-distance curve can differ from that used without greatly changing the proportion of pollen received from the various sources providea that, in all cases, there is a rapid decrease in pollen frequency with distance. For example, Wright's (1952) plot of the pollen dispersal curve for young Douglas-fir growing outside the natural range of the species was linear and showed no pollen capture beyond 150 feet. Using Wright's curve, Silen's (1962) estimate of background pollen, and the other assumptions in table 2, the pollen contribution (omitting self pollen) of the first two ranks was 75 percent, of the next seven ranks 10 percent, and of the other ranks (background) 15 percent. The example in table 3 which gave pollen contributions of 65 percent, 5 percent, and 30 percent was based on a dispersal curve which was strongly curvilinear and included pollen capture up to 250 feet.

2. Silen (1962) estimated background pollen for Douglas-fir in a large open area to be about 25 percent of that received by the sampling station at the peak of the frequency-distance curve. In the present example, a background-pollen density of 25 percent of the self-pollen density was used. Omitting self pollen, this gave estimates of orchard and

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[4/] Frank C. Sorensen. Natural selfing in coastal Douglas-fir. In preparation.

nonorchard pollen of 70 percent and 30 percent, respectively. If a background-pollen density of 5 percent of self-pollen density is used and other assumptions left unchanged, the proportions of orchard and nonorchard pollen would be about 95 percent and 5 percent, respectively. If a background-pollen density of 50 percent of self-pollen density is used, orchard and nonorchard proportions would be, respectively, about 60 percent and 40 percent. If incidence of background pollen and self pollen is assumed to be equal, the percentages of orchard and nonorchard pollen which a seed orchard tree received would be 40 and 60 percent, respectively.

3. In assumption 3, table 2, it was proposed that if the effect of distance is neglected, the sample tree receives as much pollen from itself as it does from all the trees in any one surrounding rank. However, it might also be assumed that the delivery system for self pollen is less efficient because some of the self pollen is blown directly out of the crown without opportunity to contact female strobili, whereas pollen coming from a neighboring tree will have the opportunity to pass through the entire crown of the sample tree. If self-pollen frequency in table 3 is reduced by half and other pollen frequencies are not changed, the contribution of self pollen would be reduced from about 55 percent to 35 percent. If self pollen is omitted, the proportions of near-neighbor, other-orchard, and nonorchard pollens would remain unchanged.

4. Intervening rows of trees between the sample tree and the trees from which it is receiving pollen are assumed to intercept or cause the settling-out of half of the incoming pollen (assumption 4, table 2). Changes in this fraction have their greatest effect on the proportions of near-neighbor and other-orchard pollen. Relative proportions of orchard and nonorchard pollen are affected to a lesser extent. For example, if three-fourths of the incoming pollen were intercepted per intervening row, then the estimates would be 55 percent selfing or, with selfing excluded, about 70 percent near-neighbor, less than 1 percent other-orchard, and about 30 percent nonorchard. If only one-fourth of the incoming pollen were intercepted per intervening row, selfing would be estimated at 50 percent, near-neighbor, other-orchard, and nonorchard estimates (excluding selfing) would be about 60, 25, and 15 percent, respectively.

Other factors which may affect the accuracy of the example are indicated in assumptions 5 through 9 (table 2). They include flowering time (do flower receptivity and pollen release coincide on the sample tree, between the seed tree and other-orchard trees, and between orchard trees and trees in the surrounding stands?), relative proportions of orchard and nonorchard trees which are flowering, and possible deposition of massed pollen clouds (Lanner 1966). These influences may vary greatly from area to area and some of them from year to year, so it is probably not necessary to consider them in this general situation. However, any of these factors which can be estimated can be fitted into the model.

Tree size and proportion of space occupied by tree crowns will also have to be considered if the model is used to coordinate and interpret results of pollen sampling. Both pollen production and pollen interception will be affected by crown size and density. For the present, it can only be assumed that the proportion of orchard pollen will increase rapidly after the orchard comes into production.

Selfing has been considered at the two extremes in tables 1 and 3: first, with self pollen fully as effective as cross pollen in producing viable seeds, and second, with the sample tree being self-sterile. The actual situation will usually be between these extremes.

In the example, the sample tree has been treated as receiving pollen equally from all sides. However, pollen movement may be predominantly in one direction (Dyson and Freeman 1968). In this case, the sample tree should receive pollen from a smaller number of the surrounding trees, but the relative proportions of self, near-neighbor, other-orchard, and nonorchard pollens should remain about the same as when wind movement is variable.

The example and discussion have centered on the model in relation to a seed orchard situation. This was due to the relevance of pollen dispersal to the management of seed orchards, in which pollen contamination is a serious question, and because the uniformity of a seed orchard plantation made the presentation of the model and example easier. In natural stands there will be more variability in factors such as distance between ranks of trees and number of trees per rank. But if reasonable averages can be obtained for each of these factors, it appears that the model could be employed satisfactorily to partition pollen sources for trees in a variety of natural situations.

CONCLUSION

The pollen which trees receive comes from many different sources and distances. The model presented here divides these sources into self pollen, pollen from immediate neighbors, pollen from slightly more distant neighbors, and background pollen. Data were brought together from the literature in an attempt to get a picture of pollen source as related to seed orchard trees, and also to determine what additional information might be most useful in testing the model.

Of course, the model was quite simplified. The real situation is expected to be much more complex. Nevertheless, in determining what would be the most valuable additional information, two observations seemed to be of primary importance. First, except for large depositions of background pollen, the tree itself and its immediate neighbors appear to contribute the majority of pollen which the tree receives. Second, the interception of pollen by intervening ranks of trees appears to be a very influential factor in local pollen movement. Its importance is now largely unknown.

With these two observations in mind, it appears that estimates of self-pollen contribution and pollen contribution from the neighboring two, or better three, ranks of trees would be most important for developing a picture of the pollen distribution in a seed orchard.

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NATURAL REFORESTATION AFTER LOGGING ON AFOGNAK ISLAND

by

A. S. Harris, *Principal Silviculturist*

OCT 24 1972

ABSTRACT

Observations of natural reforestation on a 100-acre cutting unit 25 years after logging showed that some areas were still dominated by grass-herbaceous vegetation and that growth of Sitka spruce seedlings was slow. This competition probably is slowing growth of trees and preventing natural restocking of spruce. If conditions described prove to be typical, measures to control competition will be necessary to insure adequate reforestation after logging on Afognak Island, Alaska.

Keywords: Natural regeneration (forests), reforestation, Sitka spruce, logging.

Afognak Island, Alaska (latitude 58°15' N., longitude 152°30' W.), lies near the extreme western limit of Sitka spruce.[1] To the west, the Alaska Peninsula and Aleutian Islands are essentially treeless.

Sitka spruce is the only conifer on Afognak Island and, although relatively new to the island, is gradually advancing west and south, invading open grass-herbaceous vegetation-covered land. Studies on nearby Kodiak Island have shown the rate of this forest advance to be about 1 mile per century (Griggs 1934).

These primary stands of Sitka spruce together with the extensive volcanic ash layer laid down by the eruptions in the Katmai region in 1912 (Griggs 1922, Martin 1913, Curtis 1955) set Afognak and the adjacent islands of Kodiak and Shuyak apart as a unique forested area.

Afognak Island, with a land area of 717 square miles, is part of the Chugach National Forest. Established in 1892 as the Afognak Forest and Fish Culture Reserve, the island was the first area included in what has come to be the National Forest System. The Sitka spruce forests of Afognak Island now include 230,000 acres of commercial forest land with a net volume of 5.3 billion board feet (Scribner) (Institute of Northern Forestry 1967).

To date, only a limited amount of timber has been cut on Afognak Island. During World War II, a few cuttings were made at Kazakof Bay and Afognak Bay to supply logs for a local sawmill operated by the U.S. Army, with lumber used in Kodiak and the Aleutians. Later, a small area was logged along Raspberry Strait to supply a local mill. This mill was destroyed by a tidal wave in 1964, and since then, no timber has been harvested on the island. Because of this limited experience with timber cutting, little is known about reforestation of Sitka spruce on Afognak Island.

In 1968 we investigated natural reforestation on a 100-acre World War II cutting unit at Kazakof Bay. The unit is on hilly topography, and soils are well drained except for small bottomland areas which are swampy or contain small ponds. In general, vegetation type is similar to that described as 6-SP (growing on soils of the Kodiak series) by Rieger and Wunderlich (1960). The unit was essentially clearcut in 1943 and 1944, with residual trees left scattered over the area (fig. 1). Logs were high-lead yarded and skidded to tidewater by cable or crawler tractor.

METHODS

During the summer of 1968, 36 circular 4-milacre plots (7.45-foot radius) were located at 2-chain (132-foot) intervals along three lines crossing the cutting unit (fig. 2). Three plots situated in swampy conditions were discarded.

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[1] Scientific names of plants mentioned are shown on page 10

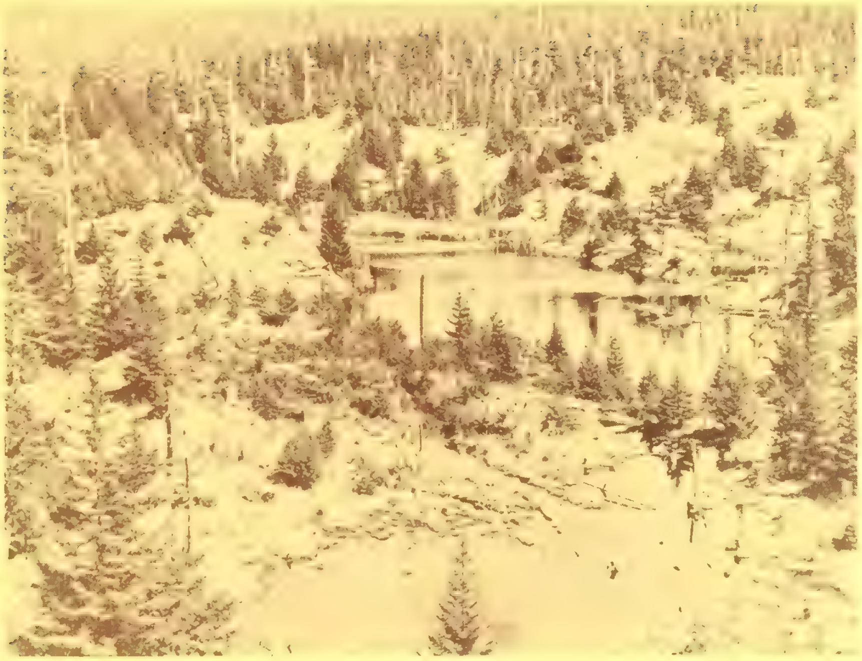

Figure 1.—Twenty-five years after logging, the cutting unit at Kazakof Bay still had an open appearance, with residual trees and advanced seedlings scattered throughout. (Photo taken May 1969.)

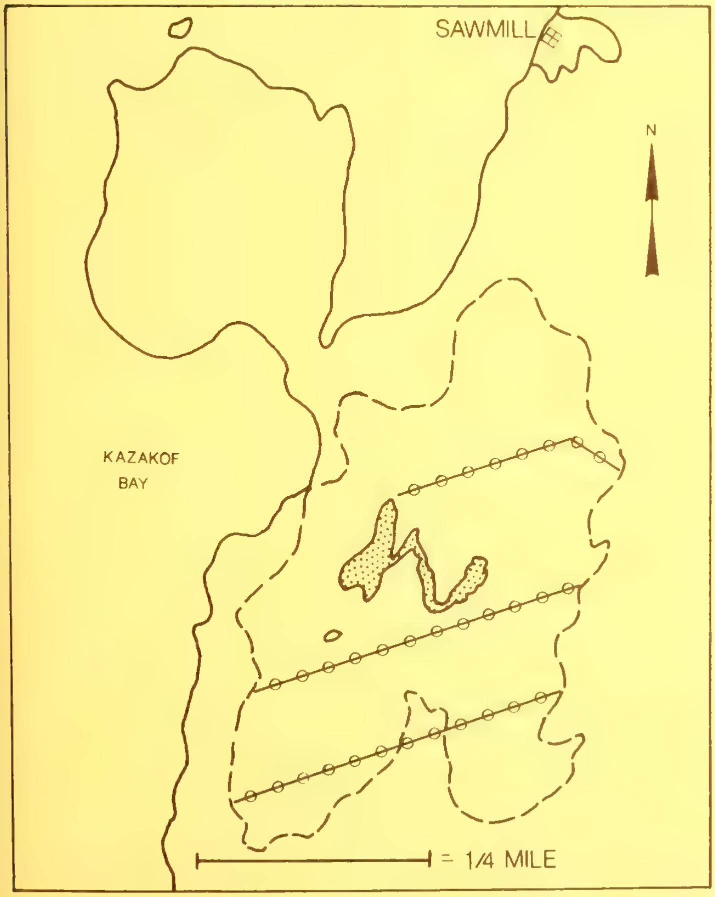

Figure 2.—Location of 4-milacre regeneration plots—World War II cutting, Kazakof Bay, Afognak Island, Alaska.

The total number of spruce seedlings on each plot was recorded. Total height and 3-year leader growth of up to three of the largest spruce on each plot were measured, and the seedbed situation of each spruce was recorded. These dominant spruce were then cut at the root collar, and annual rings were counted to determine age. Seedlings over 25 years old at root collar were classed as "advanced" seedlings, having been established before logging; and those younger, as "subsequent" seedlings, having originated from seed after logging. Other information recorded was: slope, drainage, aspect, percentage of each plot occupied by plant species or surface condition, depth of organic accumulation above volcanic ash, and depth of volcanic ash.

In 1969, nine spruce trees, which originated in the understory of the former stand and were undamaged by logging, were cut and sectioned to determine growth rate. These trees were selected from vigorous, apparently normal trees to supplement data on growth of seedlings previously measured on sample plots. Their heights ranged from 29 to 43 feet.

RESULTS AND DISCUSSION

Seventy-three percent of the plots were stocked with at least one spruce, and tree density averaged 1,740 stems per acre. This level of stocking would be considered adequate by Regional standards[2] if the survey had been made from 5 to 10 years after logging and if all seedlings were producing good growth. However, the cutting unit still had an open appearance 25 years after logging, with many areas dominated by brush, grass, and herbaceous vegetation (fig. 3).

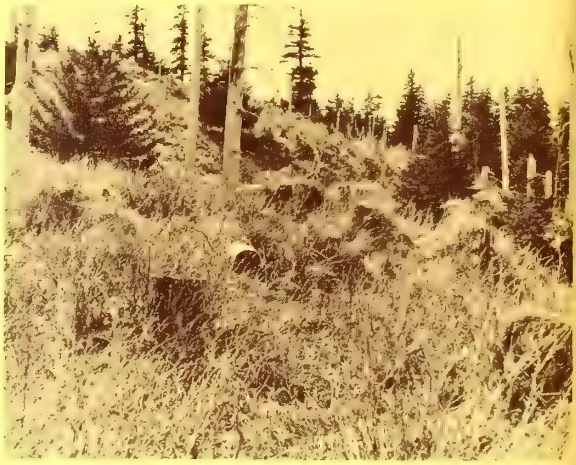

Figure 3.—Twenty-five years after logging, many portions of the cutting unit at Kazakof Bay were covered with brush. Salmonberry is the most prominent species visible in the foreground of this photo taken in May 1969.

This level of restocking is far below what one would expect on a cutting of similar age in southeast Alaska. For example, on a mile-square cutting unit in Maybeso Valley 8 years after logging, 83 percent of 4-milacre plots were stocked and stand density averaged 4,872 seedlings per acre (Harris 1967).

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[2] Region 10 stocking standards, based on the percentage of 4-milacre plots containing at least one healthy and vigorous seedling 6 inches or more in height and free to grow, are: desired stocking, 70 percent or more; satisfactory stocking, 40-69 percent; poor or unsatisfactory stocking, 10-39 percent; nonstocked, less than 10 percent.

At Kazakof Bay, growth rate of dominant spruce seedlings was slow (fig. 4), and only 30 percent of the plots contained a spruce seedling at least 4.5 feet tall. Only 21 percent of the plots contained a seedling growing at least 6 inches annually; 48 percent, 4 inches; and 70 percent, 2 inches. Slow-growing seedlings may eventually mature, but it is doubtful that many of those overtopped by dense competing vegetation or growing slowly for other reasons will develop into merchantable trees at the anticipated stand rotation age of 110 years.[3] (fig. 5).

Some plots contained seedlings established both before and after logging. Subsequent spruce were found on 67 percent of plots; advanced spruce, on 15 percent. Based on the three largest seedlings per plot, dominant subsequent seedlings became established on the cutting over an 18-year period after logging, but none thereafter (fig. 6). Sixty-six percent of the subsequent seedlings examined grew on rotten wood, upturned roots, or alongside stumps; 20 percent, on mixed organic-ash seedbeds; 9 percent, on moss; and 5 percent on shallow organic soil underlain by rock. Seedlings which were located on ash grew best, whereas seedlings which were located on rotten logs, elevated roots, stumps, or shallow moss-covered soil over rock grew more slowly.

Competition from brush, grass, and herbs appeared to be the most important factor influencing distribution and growth of seedlings (fig. 7). Nonstocked plots contained a higher proportion of fireweed, devil's club, and salmonberry than did stocked plots, but average height of these competing plant species differed little between stocked and nonstocked plots (table 1).

Average depth of volcanic ash and surface organic material differed little between stocked and nonstocked plots--on stocked plots, volcanic ash averaged 5.2 inches in depth; on nonstocked plots, 4.9 inches. Surface organic matter which had accumulated since the ashfall of 1912 averaged 4.0 inches on stocked plots and 3.7 inches on nonstocked plots.

The most prominent trees on the cutting unit were spruce that had escaped logging. Such trees were often growing at the rate of a foot or more annually, although early growth was slow (fig. 8).

Stem analysis of nine residual spruce, which were cut and sectioned in 1969, showed that height growth was not affected by the 1912 deposition of volcanic ash. Rate

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[3] W. R. Overdorff, John Galea, Lyle Jack, and others. Timber management plan, Chugach Working Circle, Alaska Region, 1967-1976. Mimeogr. Chugach National Forest, Anchorage, Alaska. 1967.

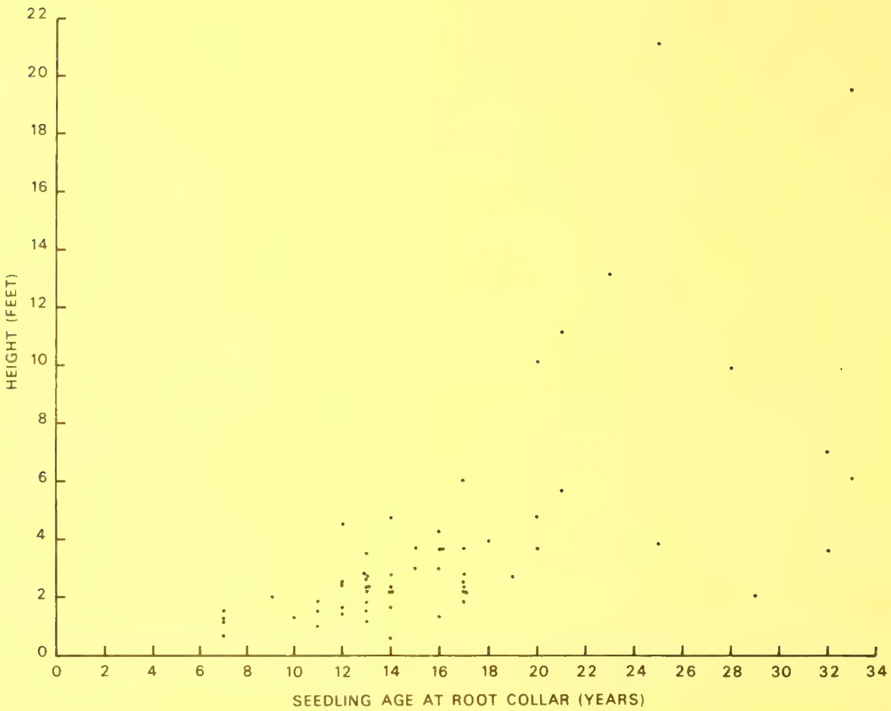

Figure 4.—Height and age of dominant spruce in 1968, 25 years after logging—World War II cutting, Kazakof Bay, Afognak Island.

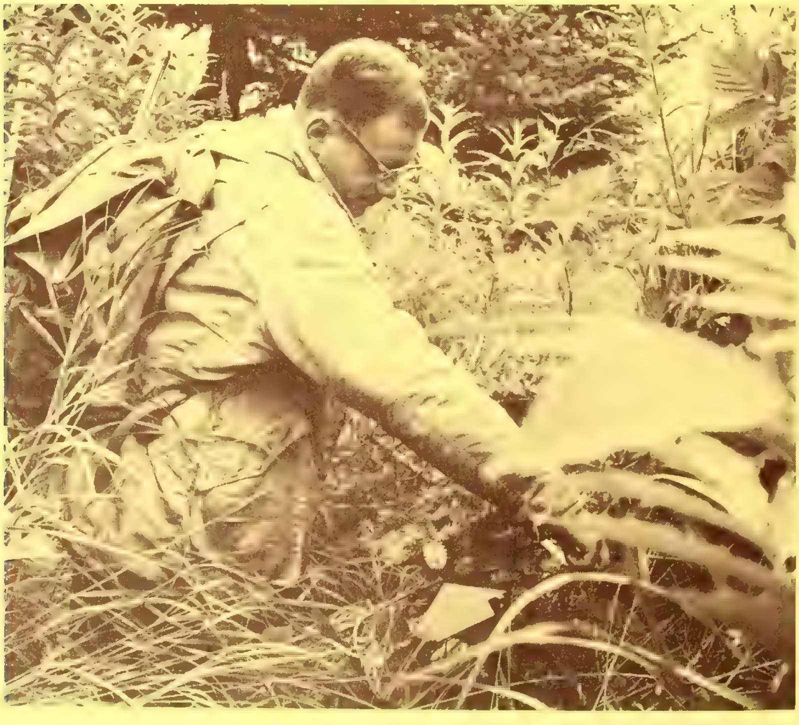

Figure 5.—Many spruce seedlings such as this one at Kazakof Bay are growing slowly. The observer is standing in dense fireweed-grass-salmonberry cover which offers severe competition for Sitka spruce. (Photographed July 1968.)

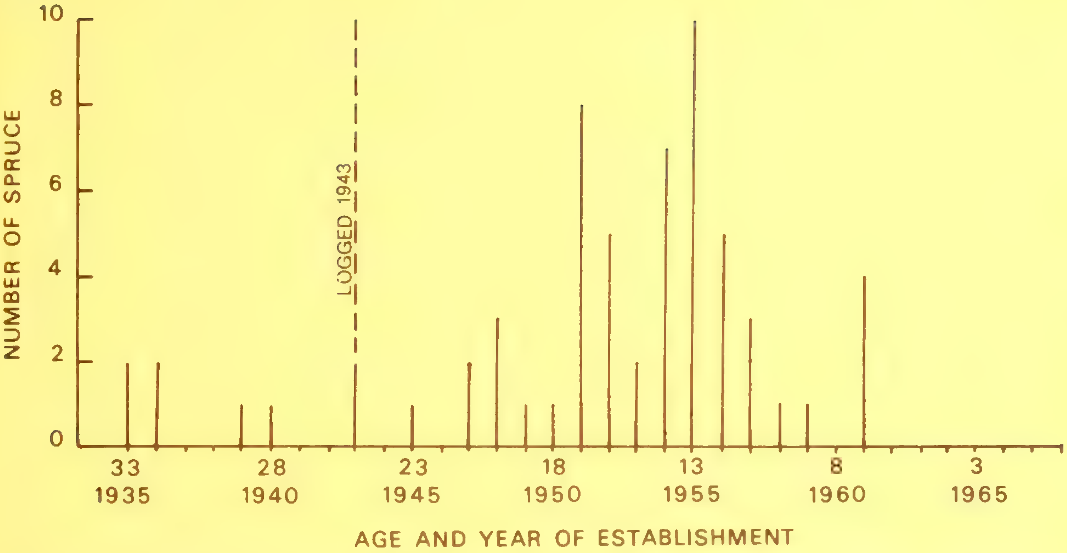

Figure 6.—Age distribution of 64 dominant spruce on 4-milacre plots in 1968, 25 years after logging—World War II cutting, Kazakof Bay, Afognak Island.

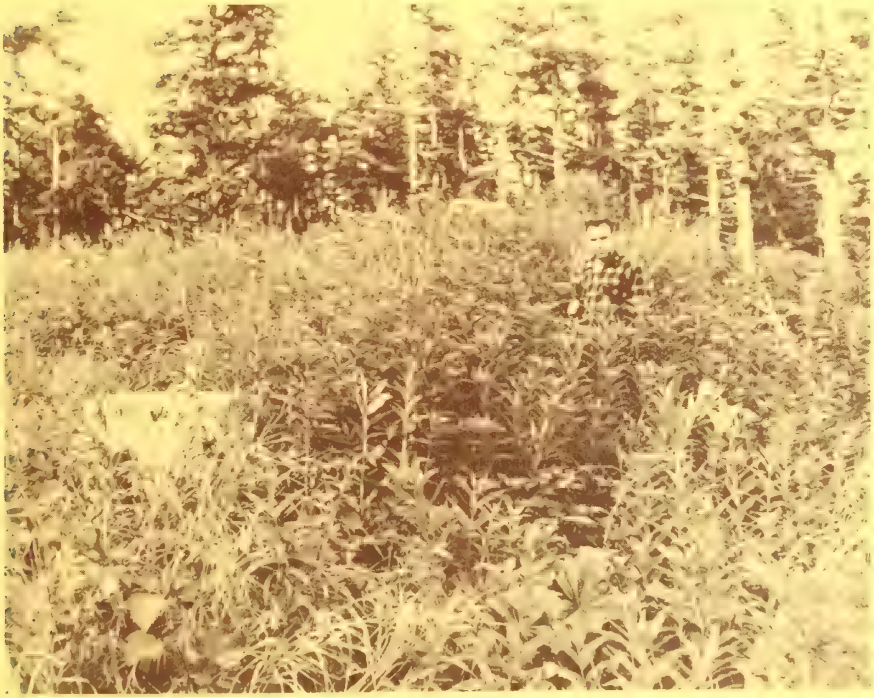

Figure 7.—Dense growth of fireweed, grass, salmonberry, and devil's club offers severe competition to establishment of Sitka spruce at Kazakof Bay. (Photographed July 1968.)

Table 1.--*Percent and height of ground cover on stocked and nonstocked 4-milacre reforestation plots, Kazakof Bay, Afognak Island, Alaska, July 1968*

Ground cover	Stocked plots		Nonstocked plots	
	Plot occupancy	Average height	Plot occupancy	Average height
	Percent	*Inches*	*Percent*	*Inches*
Grass	24	35	13	40
Fireweed	16	52	40	54
Devil's club	10	41	18	43
Salmonberry	8	38	14	35
Moss	17	--	6	--
Early blueberry	9	--	0	--
Alder	2	--	5	--
Fern	4	--	2	--
Spruce	7	--	0	--
Rotten wood	2	--	2	--
Other	1	--	0	--

of height growth increased after overstory trees were harvested (fig. 9).

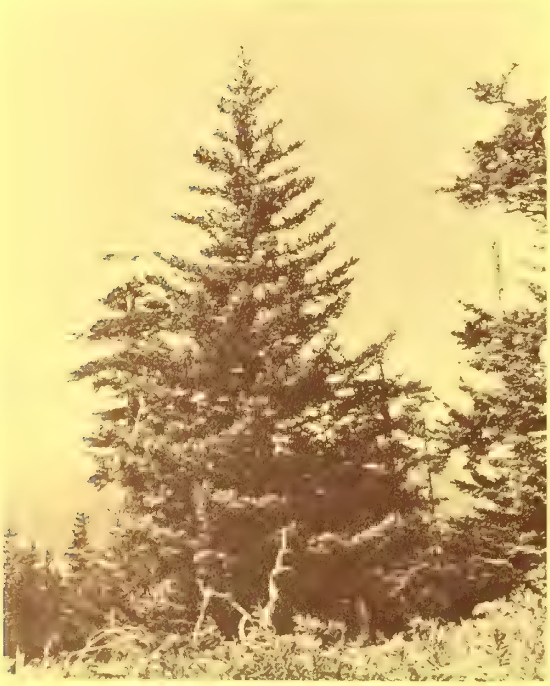

Figure 8.–In July 1969, this residual spruce was 43 feet tall and 88 years old at a 1-foot stump. Annual growth during the last 5 years averaged 1 foot. Early growth was slow.

There were few signs of recent animal damage to spruce seedlings, although 10 percent of seedlings examined showed some evidence of past browsing. Varying hares (*Lepus americanus*) were introduced on Afognak Island in 1934 and are said to have reached a population peak about 1946. Populations then declined but increased again between 1954 and 1957.[4] Population levels apparently have been low during recent years. Vincent reported that spruce needles are an

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[4] Robert Vincent. Notes on geology, history, land mammals, birds, and plants of Kitoi Bay, 67 p., 1965. (Unpublished paper on file at Forestry Sciences Laboratory, Juneau, Alaska.)

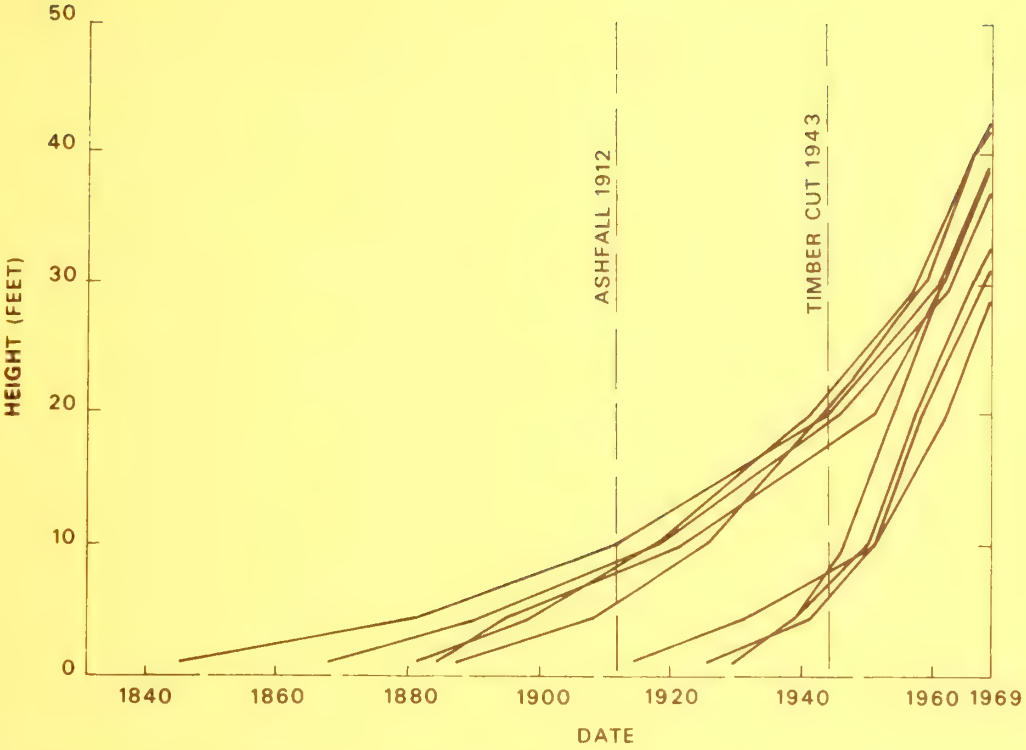

Figure 9.—Height development of nine residual spruce sectioned in 1969 had been unaffected by ashfall in 1912. Rate of height growth increased after the overstory was removed in 1943 and in 1969 was similar to that of the better growing subsequent and advanced seedlings.

important part of a hare's diet. It is possible that hares may have caused severe losses of seedlings during the population peak of 1946, but no evidence of such losses would be apparent today.

Roosevelt elk (*Cervus canadensis*) were introduced on Afognak Island in 1928 and have established sizable herds (Batchelor 1965, Troyer 1960). Although elk tracks were numerous on the cutting unit, no damage to seedlings was apparent.

Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) were introduced to Kodiak Island in 1924 and have spread to Afognak Island. Deer doubtless frequent the study area at times, but no seedling damage was observed.

Detailed records of spruce seed production on Afognak Island are lacking. Large crops of cones are known to occur, but seed quality or crop periodicity is not known. The cutting unit at Kazakof Bay is small and contains some residual seed trees, so during good seed years an adequate source of seed should be available.

CONCLUSIONS

Observations of natural reforestation at Kazakof Bay 25 years after logging showed that parts of the cutting unit were still dominated by grass-herbaceous vegetation and that many seedlings were growing slowly. Stocking density would be considered adequate if all seedlings were producing good growth, but the slow growth of many seedlings may make reforestation inadequate to meet management objectives. Dense grass-herbaceous vegetation appears to be an important factor limiting natural reforestation and is apparently slowing or preventing further natural restocking of spruce. Volcanic ash does not appear to have contributed to slow reforestation--seedlings grew best on volcanic ash seedbeds.

If conditions noted here prove to be typical, treatment to control competing vegetation, together with planting or seeding of spruce, will be necessary to regenerate stands promptly after timber harvesting. Competing vegetation might be controlled by surface scarification or by application of approved selective herbicides where environmental safety is assured.

Shelterwood cutting may prove to be an appropriate silvicultural system for use on Afognak Island. Interest is being shown in the shelterwood system because of its potential for reducing plant competition for tree regeneration in second-growth western hemlock-Sitka spruce stands in Oregon (Ruth 1965). Some modification of the system might be required for use in primary stands of Sitka spruce. Until more experience with reforestation is available, forest managers should proceed cautiously with plans for large-scale timber harvesting on Afognak Island.

COMMON AND SCIENTIFIC NAMES OF PLANTS MENTIONED

Sitka spruce — *Picea sitchensis* (Bong.) Carr.
Fireweed — *Epilobium angustifolium* L.
Devil's club — *Oplopanax horridum* (J. E. Sm.) Mig.
Salmonberry — *Rubus spectabilis* (Pursh)
Alder — *Alnus sinuata* (Reg.) Rydg.
Moss — *Musci* (class)
Fern — _Athyrium filixfemina_* (L.) Roth
Grass — _Calamagrostis canadensis_* (Michx.) Beauv.
Early blueberry — *Vaccinium ovalifolium* Sm.

*Most common species noted. Others may be represented in association but are less common.

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GPO 985-961

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USDA FOREST SERVICE RESEARCH NOTE

PNW-177
June 1972

79

PAPER BIRCH SEED PRODUCTION IN THE TANANA VALLEY, ALASKA

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SCI., TECH., & AGR. DIV.

by

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ABSTRACT

A study of seedfall was conducted from 1958 to 1963 in four *Betula papyrifera* stands near Fairbanks, Alaska. Total seed crops varied between 542 and 72,805 seeds per square meter; viable seed per square meter varied between 42 and 27,520. Seed crops adequate for natural regeneration of 100-foot-wide clearcuts occur in at least 1 out of 4 years in this portion of the taiga.

Keywords: Forest seed production, paper birch, *Betula papyrifera*.

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The paper birch (*Betula papyrifera* Marsh.) forest type covers over 5 million acres of Alaska (Hutchison 1967). Many of these stands originated from seed following destruction of the previous stands by fire (Lutz 1956, Gregory and Haack 1965). Obviously, information on seed production characteristics of this species will enhance our knowledge of its natural regeneration. We report, here, the results of a study of the quantity and quality of paper birch seed crops.

MATERIALS AND METHODS

The study was conducted in four pure, even-aged paper birch stands (table 1). All were located on upland sites within 80 miles of Fairbanks (64°51' N., 147°44' W.) Ten seed traps each were systematically placed in stand 3 in 1958, stands 1 and 4 in 1959, and stand 2 in 1960. The study was concluded in May 1963.

During 2 of the 5 seed years studied (1958-59 and 1959-60), traps made from galvanized flue thimbles were used (fig. 1A). These were not entirely satisfactory because fallen leaves could temporarily cover the hardware cloth openings on the trap surface. These leaves could then be blown away taking with them any seed which may have fallen on their surface. In this way small quantities of seed may have been lost from the traps, although they were cleaned frequently during the periods of leaf fall. We eliminated this problem by replacing the flue thimbles with a new type trap constructed from tractor funnels (fig. 1B). The hardware cloth surface of the tractor funnel traps was recessed

Table 1.--*Description of study areas*

Stand variable	Stand 1	Stand 2	Stand 3	Stand 4
1959 stand age . . . . (years)	47	68	81	99
Height of average dominant and codominant . . . . . (feet)	50	58	60	69
. . . . (meters)	15.2	17.7	18.3	21.0
Site index [1]	57	51	49	52
Number of trees per acre	1,215	931	645	292
Number of trees per hectare	3,002	2,300	1,594	722
Basal area . . . . (square feet per acre)	94	108	102	90
. . . . (square meters per hectare)	22	25	23	21
Average diameter at breast height . . . . (inches)	3.8	4.6	5.4	7.5
. . . . . (centimeters)	9.6	11.7	13.7	19.0
Percent of normal basal area[2]	94	106	100	85

[1] Based on height of average dominant and codominant trees at breast height, age 50 years (Gregory and Haack 1965).

[2] When dominant and codominant tree crowns occupy most of the available growing space.

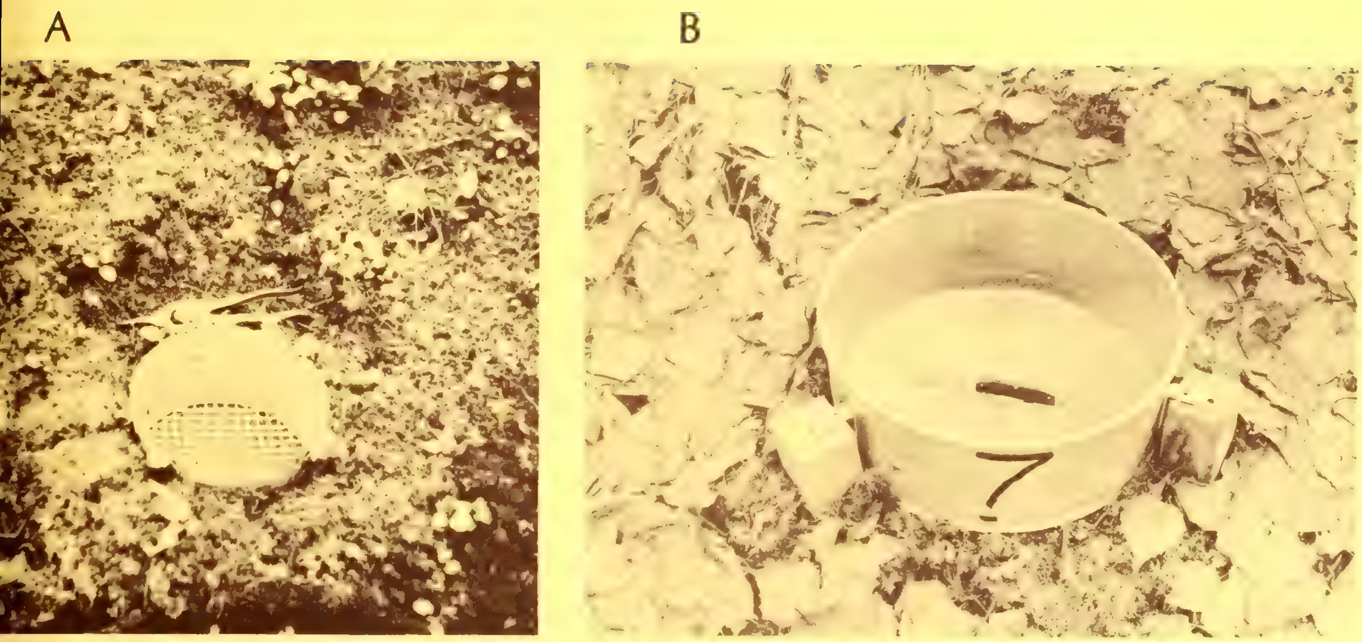

Figure 1.--Seed traps: *A*, Thimble trap in place (surface area, 0.041 square meter); *B*, funnel trap in place (surface area, 0.050 square meter).

so that leaves accumulating on the recessed surface were not blown away.

The seed traps were in place by early July of each year. They were emptied as soon as the ground surface was almost free of snow, usually early May of the following year. No attempt was made to determine when seed fell.

Germination tests were made immediately after the seed was removed from the traps. A sample of 1,000 seeds (ten 100-seed replications) from each stand, consisting of an equal number of seed from each trap, was germinated on water-soaked cellulose pads in petri dishes and placed in a germinator with alternating 12-hour periods at 68° and 86° F. The seeds were exposed to weak light. Germinants were counted and removed at 2-day intervals. The tests were terminated when no germination was observed over a 5-day period. A seed was considered to have germinated if an epicotyl or radicle was observed emerging from the seedcoat.

Remaining seed from the emptied traps was air-dried at room temperature and stored at 35° to 40° F. Seeds from six randomly selected traps in each stand were counted. If the mean number of seeds per trap for the six traps had a sampling error over 10 percent at $p = 0.05$, then either seeds from additional traps were counted until a sampling error of 10 percent or less was attained or seeds from all traps were counted.

RESULTS AND DISCUSSION

The total number of seeds produced, viability, and sampling errors for the four stands are presented in table 2. The average annual seed production was 23,303 seeds per square meter; the lowest estimate was 542 and the largest, 72,805. Sampling error (p = 0.05) for total seed production averaged 14 percent, ranging between 4 and 32 percent. Sampling error was considerably higher for viability than for production, averaging 36 percent and varying between 10 and 68 percent.

The most significant variable for natural regeneration potential of a seed crop is the number of viable seeds potentially available to produce seedlings. We should emphasize that our estimates approximate the viability of seed overwintered under natural conditions. Although this means of determining viability is realistic, it may have underestimated the seed crop quality for birch as determined by others (Sarvas 1952, Bjorkbom et al. 1965, Horsley and Abbott 1970, Bjorkbom 1971).

Marquis (1969) has suggested classes[1] for rating viable seed crops of paper birch in New England. Although his classes are arbitrary and may not apply as well to Alaskan conditions, they provide a means of rating seed crops. On this basis, three crops (stand 3, 1958; stands 1 and 2, 1960) were much larger than the bumper crop threshold value; three somewhat below the bumper range but far above average (stand 3, 1959 and 1960; stand 4, 1962); seven average to above average crops; one poor (stand 1, 1962); two very poor (stands 1 and 2, 1961). On this basis, Alaskan seed crops appear to be somewhat above average New England standards.

Estimates of the number of viable seeds required to adequately regenerate a cutover vary. Horsley and Abbott (1970) recommended a rate of 500,000 viable seeds per acre (121 per square meter) on partially shaded, narrow (50 feet wide), scarified clearcut strips and 1,000,000 viable seeds per acre (242 per square meter) on more exposed sites (e.g., wider clearcuts). Bjorkbom (1971) recommended a rate of between 630,000 and 800,000 viable seeds per acre on untreated seedbeds. Using the more conservative of these estimates and the estimate that birch seedfall at 100 feet from the seed source will be 20 percent of that in the stand (Bjorkbom 1971), we can predict that the ability of these Alaskan stands to regenerate a 100-foot-wide clearcut was: stand 1, 1 in 4 years; stand 2, 1 in 3 years; stand 3, 3 of 5 years; and stand 4, 1 of 4 years. Although these estimates are probably conservative, they do point out that large quantities of seed are required for adequate

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[1] *Bumper crop: 15,000,000 seeds per acre (3,626 per square meter). Average crop: 1,000,000 seeds per acre (242 per square meter). Poor crop: 500,000 seeds per acre (121 per square meter). Very poor crop: 250,000 seeds per acre (61 per square meter).*

Table 2.--*Estimates of total and viable seed production and sampling errors for Alaskan paper birch stands, 1958-63*

Seed year and stand number	Estimated total number of seeds per square meter	Sampling error (percent)	Viability (percent)	Estimated viable seed per square meter	Sampling error (percent)
1958-59:[1]					
1	--	--	--	--	--
2	--	--	--	--	--
3	72,805	4.0	37.8	27,520	9.5
4	--	--	--	--	--
1959-60:[1]					
1	3,681	11.0	11.4	420	32.8
2	--	--	--	--	--
3	23,831	10.0	10.6	2,526	25.0
4	19,839	10.7	1.7	337	61.7
1960-61:[1]					
1	40,396	10.4	32.4	13,088	21.3
2	55,526	9.8	41.6	23,099	30.3
3	21,536	8.9	12.8	2,757	32.9
4	42,547	7.5	1.1	468	68.4
1961-62:					
1	542	14.2	16.0	87	(2)
2	1,045	22.2	4.0	42	(2)
3	1,878	25.7	27.2	511	(2)
4	4,182	31.9	12.7	531	(2)
1962-63:					
1	16,282	16.6	.8	130	63.2
2	22,033	14.7	3.7	815	58.4
3	9,700	21.4	7.9	766	14.2
4	21,026	11.3	9.7	2,036	17.4

[1] 10 seed traps each were systematically placed in stand 3 in 1958, stands 1 and 4 in 1959, and stand 2 in 1960.

[2] Not determined because of small quantity of seed.

regeneration of this species. Bjorkbom (1971) presents a more detailed discussion of the relationship between seed crops, seed dispersal, and width of cutting.

The stands used for this study represented a range of age (47, 68, 81, and 99 years) and density (3,002; 2,300; 1,594; and 722 trees per hectare. However, site index (57, 51, 49, and 52) and basal area (22, 25, 23, and 21 square meters per hectare) were similar for all four stands (table 1). Analysis of variance of data for 1960-63 seed years revealed no significant difference ($p = 0.05$) between these stands in either the total number of seeds produced or their viability. Longer term records may be required to reveal significant differences in seed production between different age and density stands. In addition the overwintering of the seed may have reduced variability in seed crop quality.

Although informative, comparison of seed crops between regions for the same or similar species is difficult because of different methods. However, similar data are available for the same or similar species in other areas. New England seed crops (average 2,715 seeds per square meter; largest 6,303 seeds per square meter) for the period 1958-60 were lower than Alaskan crops (Bjorkbom et al. 1965). Greater seed production in these Alaskan stands does not conform to the more common observation of decreasing seed production with increasing latitude for other species (e.g., Sarvas 1957, Andersson 1965). At similar latitudes (60° N.) in Finland, *B. verrucosa* averaged 34,271 seeds per square meter, with a maximum annual production of 72,426 seeds per square meter. *B. pubescens* averaged 30,731 seeds per square meter, with a maximum of 60,010 seeds per square meter (Sarvas 1952). Although somewhat larger than Alaskan crops, the Finnish seed crops are of the same order of magnitude and much larger than New England seed crops.

It is even more difficult to compare seed crop quality for these three regions because of the great difference in methods used. For example, Sarvas (1952) based his viability estimate on microscopic examination of the seed and used no germination test. Bjorkbom et al. (1965) based their viable seed percentage on germination of seed collected from seed traps monthly from August to November and in the spring. New England seed viability ranged between 13 and 77 percent with an average of 37 percent. Seed crop quality for both Finnish species was about 45 percent. Variation for *B. verrucosa* was from 6 to 64 percent; for *B. pubescens*, the range was from 18 to 55 percent (Sarvas 1965). Germination values from New England and Finland seem to be generally higher than those observed for Alaska. However, germination tests of seed collected from Alaskan birch trees in 1969 and 1970 and stored at 34° to 40° F. yielded percentages of 50 and 70 percent,[2/] respectively. These tests suggest that Alaskan seed viability may be much closer to New England and Finnish values than the values observed in this study.

CONCLUSION

This study quantifies the observation that paper birch stands produce large quantities of seed almost every year. Based on our seed viability data and information from elsewhere, we suggest that seed crops adequate for natural regeneration of 100-foot-wide clearcuts occur in at least 1 out of every 4 years in this portion of the taiga.

[2/] *Unpublished data on file at Institute of Northern Forestry, Fairbanks, Alaska.*

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GPO 985-997

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79 PNW-178

May 1972

AVERAGE YARDING DISTANCE ON IRREGULAR-SHAPED TIMBER HARVEST SETTINGS

by

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and

J. Doyle Burke, *Civil Engineer*

ABSTRACT

Average yarding distance and area are determined for irregular harvest settings using the method of moments and a desk-top programable calculator with digitizer. The method, fast and accurate, should be useful to those involved in timber sale layout and appraisal.

Keywords: Forest cutting systems, mathematical instruments, digitizer.

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INTRODUCTION

The trend to natural-shaped cutting units *(6, 7)* poses new problems in rapidly and accurately determining area and average yarding distance. Easy methods for determining the average yarding distance and area are available for simple shapes of right triangles, rectangles, and circular arcs. The average yarding distance and area of irregular shapes can be determined by methods of numerical integration, a manual procedure much too time consuming for practical use.

This research note presents a simple and accurate technique for obtaining area and average yarding distance of a setting of any shape using a programable calculator with a peripheral digitizer. The digitizer transfers the necessary information from the map to the calculator which is programed to compute area and average yarding distance *(AYD)*.

APPLICATIONS

The major applications of the method presented in this note are in forest engineering design, sale layout, and sale appraisal. All three require cutting unit area and *AYD* as part of their functional input into the timber harvest planning process.

The forest engineer is concerned with determining equipment needs and physical design data for each harvest unit. Area and *AYD* are necessary to determine logging costs and are used in evaluating spar locations, road locations, and outer yarding limits. In addition, this information should be used to provide landscape architects with the physical limitations of the harvest system consistent with esthetic requirements, allowing both disciplines to maintain high standards of quality.

Sale layout and appraisal are concerned with stumpage costs, volumes per acre, adherence to guidelines established by the logging system selected, and landscape esthetics. Costs, timber volumes, and esthetics require information on *AYD* and area.

In addition, the method presented in this note is useful for determining areas of logged units, rock outcrops, existing right-of-way, and inaccessible timber. All are important elements of the timber harvest plan, which can be obtained without changing methods or procedures.

PROBLEM FORMULATION

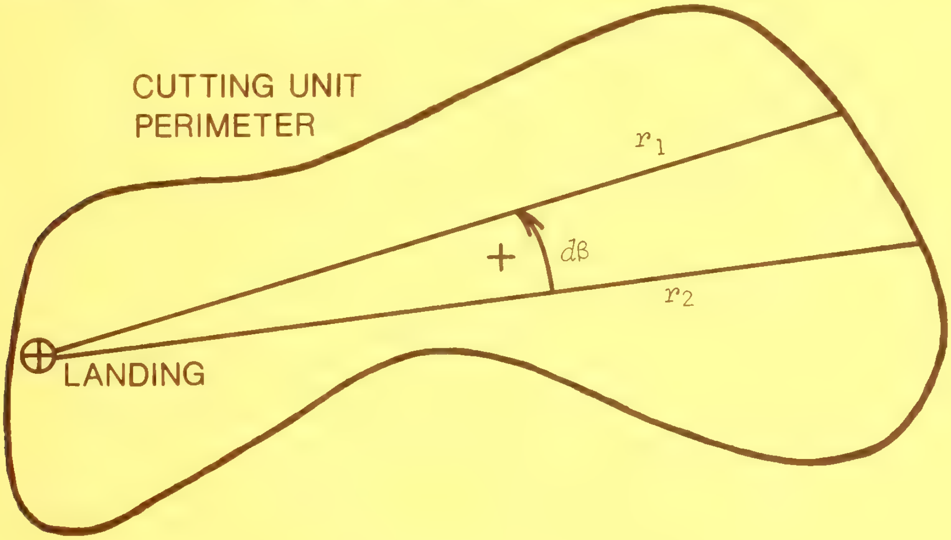
Matthews *(3)* used the method of equal areas to calculate AYD as early as 1942. This method was used for many years and is still used by some today. Lysons and Mann *(2)* showed that for a circular cutting unit, the method of equal areas gave an incorrect result. Their analysis showed that, in general, the AYD is given by

$$AYD = \frac{\int y da}{\int dA} = \frac{\text{First moment of area}}{\text{Area}} \qquad (1)$$

Equation 1 can be used to calculate the AYD for other geometric shapes.

Suddarth *(4)* presents AYD for right triangles, rectangles, and circular arcs. He also presented a method of calculating AYD of a composite area for which the respective AYD's are known. For complex areas, Suddarth recommends numerical integration.

The programable calculator-digitizer method presented in this note uses an algorithm based on equation 1 as follows:



$$dA = 1/2\ r^2\ d\beta \simeq 1/2 \left(\frac{r_1 + r_2}{2}\right)^2 d\beta$$

$$dM = (2/3\ r)\ dA = 1/3\ r^3\ d\beta \simeq 1/3 \left(\frac{r_1 + r_2}{2}\right)^3 d\beta$$

$$M = \Sigma_A\ dM$$

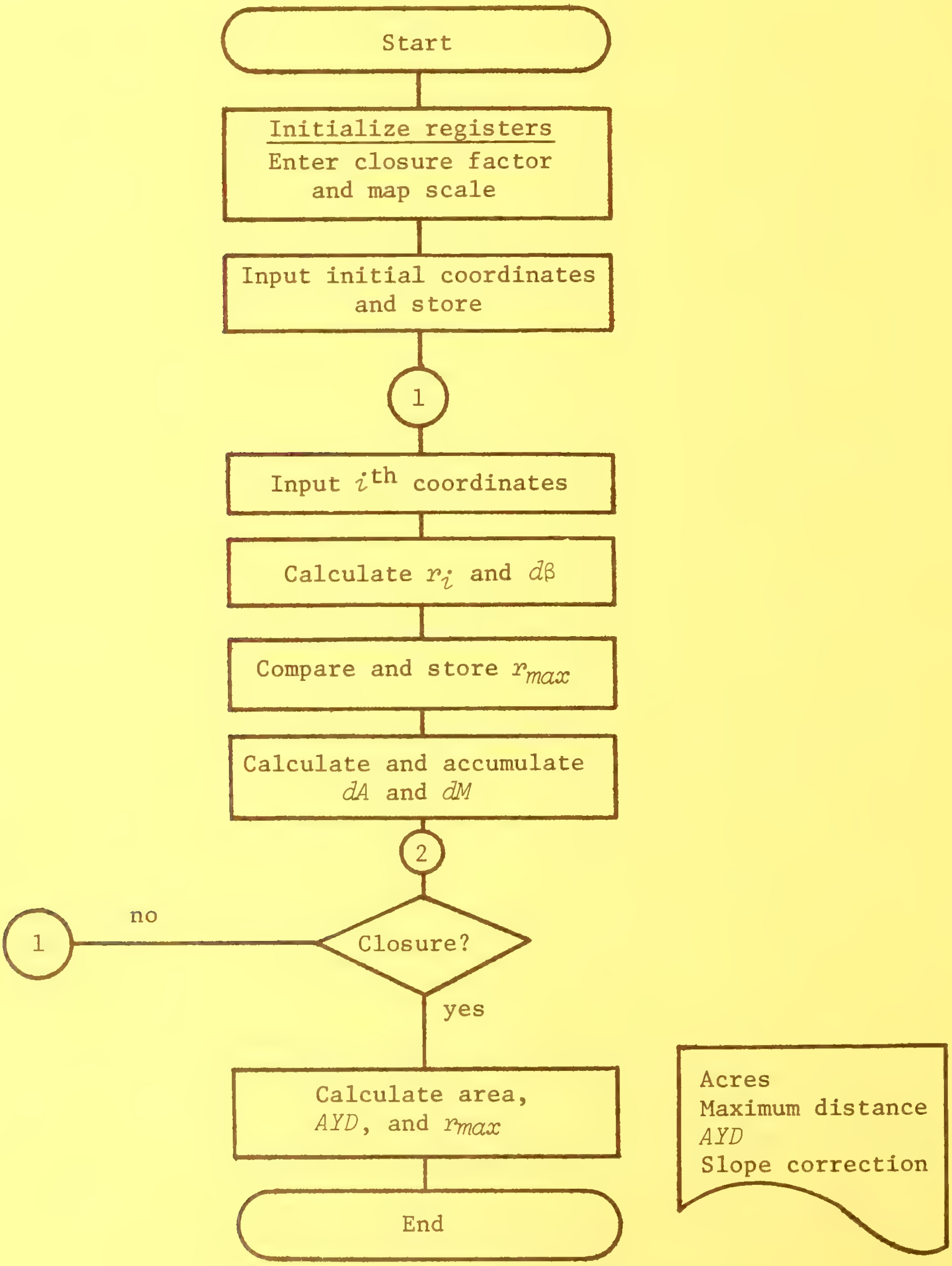
$$A = \Sigma_A\ dA$$

and

$$AYD = \frac{M}{A}$$

GENERAL LOGIC

The digitizer provides continuous x and y coordinate data to the calculator. The calculator converts this data to angles (β) and distances (r) used in computing incremental areas (dA) and moments (dM). The generalized logic is illustrated in the following flow diagram:


Start
Initialize registers
Enter closure factor and map scale
Input initial coordinates and store
1
Input i^{th} coordinates
Calculate r_i and $d\beta$
Compare and store r_{max}
Calculate and accumulate dA and dM
2
Closure?
no
1
yes
Calculate area, AYD, and r_{max}
End
Acres
Maximum distance
AYD
Slope correction

PREPARATION OF DATA

Procedures for planning sales, sale layout, and sale appraisal are documented in the Forest Service Manual *(5)*, research publications *(1)*, and in standard timber harvesting references. No attempt will be made in this note to present the details of sale design.

The method presented here requires that the cutting unit be laid out on a planimetric map of known scale. If slope corrections are required, then average slope must be determined or layout made on a topographic map. The cutting unit perimeter should be located in accordance with sale requirements and the location of the landings determined.

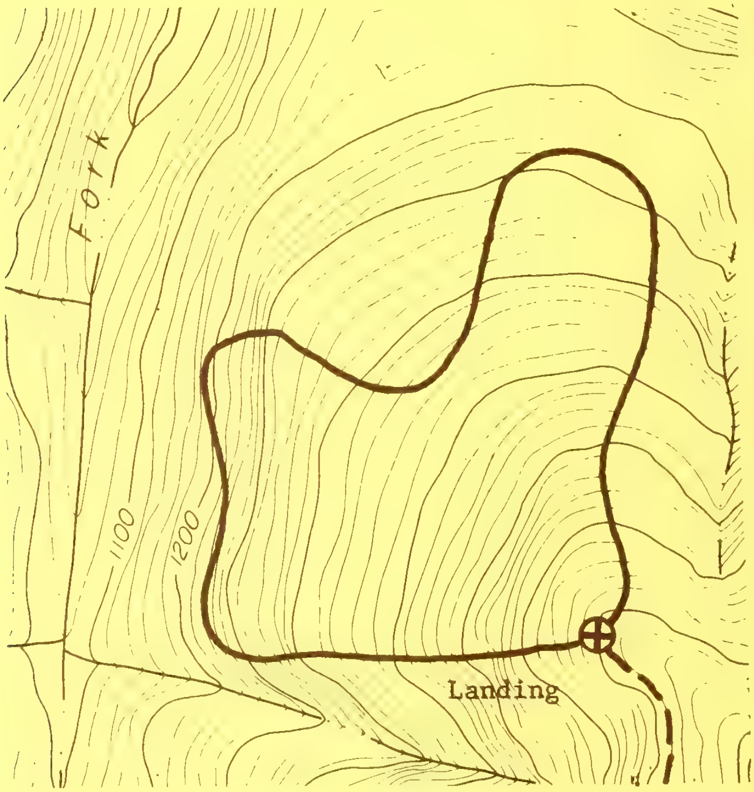
EXAMPLE DATA

Figures 1, 2, and 3 illustrate examples of timber harvest settings overlaid on topographic sections and the printer output from the programable calculator. Average time to set up and digitize each unit, including output, was 50 seconds.

Figures 1 and 2 are small, somewhat irregularly shaped units typical of short reach grapple-yarding methods. Figure 3 is a very irregular, relatively large setting, with an area of leave timber between the landing and the maximum corner. Irregular-shaped units, such as shown in figure 3, are visually more pleasing when viewed as part of the background. In contrast, an equivalent area rectangular cutting unit would appear larger, with its harsh, straight lines, and hence more objectionable.

Printer output for each unit displays the acreage of the unit, the maximum horizontal yarding distance, the average horizontal yarding distance, and the *AYD* corrected for slope.

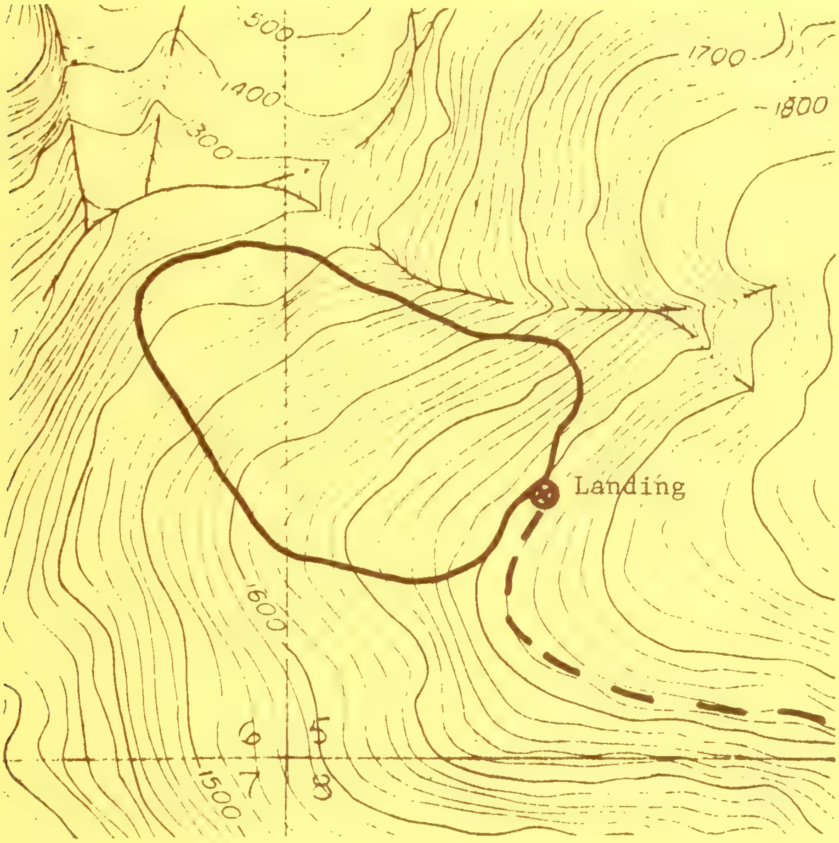
Figure 1.--Small, irregular-shaped cutting unit.



Horizontal scale: 1 inch = 200 feet
Vertical scale: 20 feet
Average slope = 100 percent

Acres	3.81
Maximum distance	518.19 feet
AYD	296.84 feet
Slope correction	420.00 feet

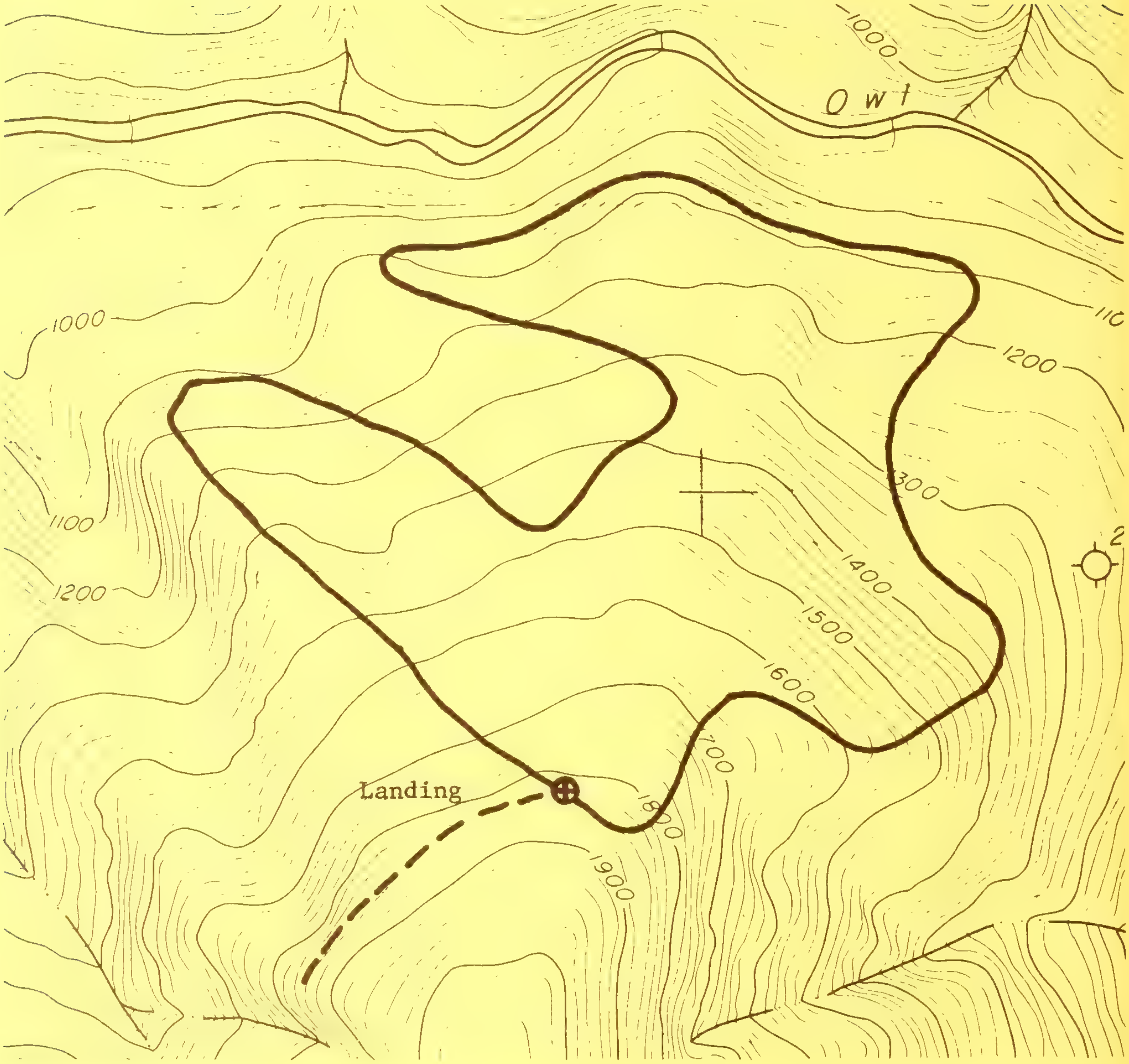
Figure 2.--Small, irregular-shaped cutting unit.



Horizontal scale: 1 inch = 400 feet
Vertical scale: 20 feet
Average slope = 50 percent

Acres	9.70
Maximum distance	926.65 feet
AYD	460.16 feet
Slope correction	514.00 feet

Figure 3.--Large, irregular-shaped cutting unit.



Horizontal scale: 1 inch = 500 feet
Vertical scale: 20 feet
Average slope = 40 percent

Acres	50.00
Maximum distance	1,850.00 feet
AYD	1,011.83 feet
Slope correction	1,090.00 feet

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OPERATING PROCEDURES

The method presented in this note was developed using a Hewlett-Packard[1/] 9100B Programable Calculator, 9107A Digitizer, and 9120A Printer. The following operating procedures and program are for the above equipment.

1. Digitizer: On
2. Calculator: On
3. Set: Radians
4. Set: Fixed
5. Decimal Wheel at 2
6. Printer on x
7. Enter program A at + (0)(0)
8. Enter program B at - (0)(0)
9. Press: End, Continue
10. Enter E (automatic closure in x register) Note: Program assumes E = 0.05 unless changed.
11. Press: Continue
12. Enter: Horizontal map scale in x register
13. Press: Continue
14. Move cursor to initial origin
15. Press: $\boxed{0}$ on cursor
16. Move cursor to landing
17. Press: $\boxed{C}$ on cursor
18. Trace cutting unit perimeter in counterclockwise direction until audible signal is heard
19. Press: $\boxed{C}$ on cursor
20. Printer will display: Acres
    Max. Yarding Dist. (Hor.)
    AYD (Hor.)
21. Enter: Average slope as a decimal (60 percent = .60) in x register
22. Press: Continue
23. Printer will display: AYD (corrected for slope)
24. For new setting, re-enter program A at + (0)(0) (Program A is destructive in register 0) and return to instruction 9.

[1/] *The use of trade, firm, or corporation names in this publication is not an official endorsement or approval by the U.S. Department of Agriculture of any product to the exclusion of others which may be suitable.*

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Title Average Yarding Distance and Area of Irregular Setting

Step +	Key	Code	Display x	Display y	Display z
0 0	CLR	20	0	0	0
1	.	21			
2	0	00			
3	5	05			
4	STP	41	ε		
5	XTO	23			
6	9	11			
7	STP	41	Scale		
8	XTO	23			
9	–	34			
a	b	14			
b	CNT	47			
c	CNT	47			
d	CNT	47			
1 0	CLR	20	0	0	
1	XTO	23			
2	0	00			
3	FMT	42			
4	.	21	X_1	Y_1	
5	XTO	23			
6	a	13			
7	YTO	40			
8	b	14			
9	FMT	42			
a	.	21	X_2	Y_2	
b	UP	27			
c	a	13	X_1	X_2	Y_2
d	–	34			
2 0	b	14			
1	RUP	22			
2	XEY	30			
3	–	34			
4	DN	25			
5	XEY	30	ΔX_2	ΔY_2	
6	POL	62	r_2	β_2	
7	XTO	23			
8	d	17			
9	XTO	23			
a	0	00			
b	YTO	40			
c	c	16			
d	FMT	42			

Step +	Key	Code	Display x	Display y	Display z
3 0	.	21	X_i	Y_i	
1	UP	27			
2	a	13			
3	–	34			
4	b	14			
5	RUP	22			
6	XEY	30			
7	–	34			
8	DN	25			
9	XEY	30	ΔX_i	ΔY_i	
a	POL	62	r_i	β_i	
b	XTO	23			
c	–	34			
d	f	15			
4 0	YTO	40			
1	–	34			
2	e	12			
3	XFR	67			
4	0	00			
5	UP	27		STORE	
6	XFR	67		r_{max}	
7	–	34			
8	f	15			
9	X<Y	52			
a	5	05			
b	0	00			
c	XTO	23			
d	0	00			
5 0	XFR	67			
1	–	34			
2	e	12			
3	UP	27			
4	XFR	67			
5	–	34			
6	f	15			
7	UP	27			
8	d	17			
9	YTO	40			
a	d	17			
b	+	33			
c	2	02			
d	÷	35			

Step +	Key	Code	Display x	Display y	Display z
6 0	c	16			
1	RUP	22			
2	XEY	30			
3	YTO	40			
4	c	16			
5	–	34			
6	DN	25			
7	XTO	23			
8	–	34			
9	c	16			
a	YTO	40			
b	–	34			
c	d	17			
d	UP	27			
7 0	UP	27			
1	|Y|	55			
2	5	05			
3	X>Y	53			
4	–	34			
5	1	01			
6	6	06			
7	GTO	44			
8	–	34			
9	0	00			
a	0	00			
b					
c					
d					

+	Storage
f	ΣdA
e	ΣdM
d	r (CURRENT r)
c	β_i
b	Y_i
a	X_i
9	ε
8	AYD (TEMP)
7	
6	
5	PROG A
4	
3	
2	
1	
0	Max r

Title Average Yarding Distance and Area of Irregular Setting (continued)

Step	Key	Code	Display			Step	Key	Code	Display			Step	Key	Code	Display		
			x	y	z				x	y	z				x	y	z
0 0	DN	25				3 0	XEY	30	dA	dM		6 0	÷	35	Ain^2	AYD	5
1	π	56				1	AC+	60				1	YTO	40			
2	+	33				2	IFG	43				2	+	33			
3	+	33				3	5	05				3	8	10			
4	YTO	40				4	a	13				4	X	36			
5	-	34				5	XFR	67				5	YTO	40			
6	c	16				6	9	11				6	-	34		STORE	
7	|Y|	55				7	UP	27				7	e	12		AREA &	
8	5	05				8	d	17				8	XTO	23		Mom (in)	
9	X>Y	53				9	|Y|	55				9	-	34			
a	-	34				a	X<Y	52				a	f	15			
b	1	01				b	4	04				b	UP	27			
c	6	06				c	4	04				c	XFR	67			
d	DN	25				d	XEY	30				d	+	33			
1 0	π	56				4 0	CHS	32				7 0	8	10	A	AYD	5
1	-	34				1	XTO	23				1	XEY	30			
2	-	34				2	9	11				2	FMT	42			
3	YTO	40				3	XEY	30				3	RDN	31			
4	-	34				4	XEY	30				4	PSE	57			
5	c	16				5	XFR	67				5	FMT	42		AUDIBLE	
6	XFR	67				6	9	11				6	RDN	31			
7	-	34				7	+	33				7	PSE	57			
8	d	17				8	CLX	37				8	FMT	42			
9	UP	27				9	X>Y	53				9	RDN	31			
a	XFR	67				a	5	05				a	XFR	67			
b	-	34				b	2	02				b	-	34			
c	c	16				c	GTO	44				c	b	14			
d	UP	27				d	+	33				d	X	36			
2 0	2	02				5 0	2	02									
1	÷	35				1	d	17									
2	DN	25				2	SFL	54									
3	XEY	30				3	b	14									
4	X	36				4	UP	27									
5	X	36	r	dA	r	5	a	13									
6	UP	27				6	GTO	44									
7	DN	25				7	+	33									
8	X	36				8	3	03									
9	2	02				9	1	01									
a	X	36				a	RCL	61									
b	3	03				b	UP	27									
c	÷	35				c	5	05									
d	DN	25				d	RDN	31									

Storage

	+	−
f	r_i	Final Area
e	β_i	Final Mom
d	r	
c	Area Ft.^{2}	
b	S_{map}	
a		
9		
8		
7		
6		PROG B
5		
4		
3		
2		
1		
0		

Title Average Yarding Distance and Area of Irregular Setting (continued)

Step	Key	Code	Display			Step	Key	Code	Display			Step	Key	Code	Display		
			x	y	z				x	y	z				x	y	z
8 0	UP	27	S	S	AYD	0						0					
1	X	36		S^2		1						1					
2	f	15	Ain^2			2						2					
3	X	36		Aft^2		3						3					
4	YTO	40		Aft^2	AYD	4						4					
5	–	34				5						5					
6	c	16				6						6					
7	4	04				7						7					
8	3	03				8						8					
9	5	05				9						9					
a	6	06				a						a					
b	0	00				b						b					
c	÷	35		Ac	AYD	c						c					
d	DN	25	Ac			d						d					
9 0	PNT	45				0						0					
1	XFR	67				1						1					
2	0	00	r_{max}			2						2					
3	YEX	24				3						3					
4	–	34				4						4					
5	b	14				5						5					
6	X	36				6						6					
7	DN	25				7						7					
8	PNT	45	r_{max}			8						8					
9	RDN	25				9						9					
a	PNT	45	AYD			a						a					
b	UP	27				b						b					
c	X	36				c						c					
d	UP	27				d						d					

Step	Key	Code	x	y	z	Step	Key	Code	x	y	z
a 0	STP	41	SLOPE			0					
1	X	36				1					
2	DN	25				2					
3	UP	27				3					
4	X	36				4					
5	DN	25				5					
6	+	33				6					
7	DN	25				7					
8	$\sqrt{x}$	76				8					
9	INT	64				9					
a	PNT	45	AYD	(CORR.)		a					
b	SPC	45				b					
c	SPC	45				c					
d	END	46				d					

Storage	
f	
e	
d	
c	
b	
a	
9	
8	
7	
6	
5	
4	
3	
2	
1	
0	

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USDA FOREST SERVICE RESEARCH NOTE

PNW-179

May 1972

LARGE-CROWNED PLANTED PONDEROSA PINE RESPOND WELL TO THINNING

by

James W. Barrett, *Silviculturist*

ABSTRACT

Sizable reductions in growing stock are feasible in overstocked ponderosa pine plantations where tree crowns are well formed and full. Thirty-year-old planted stands thinned to 140 trees per acre produced about the same volume as similar thinned stands containing four times as many trees. Understory vegetation in this study did not offer the severe competition to tree growth that was observed in brush areas near Bend, Oregon, and stands produced 70 to 90 cubic feet annually 5 years after thinning. Trees at the widest spacing (17.6 by 17.6 feet) grew in diameter at an average rate of 2.7 inches per decade, and those at narrowest spacing (8.8 by 8.8 feet) grew less than 1 inch per decade. Height growth was not affected by thinning intensity.

Keywords: Thinning (trees), stand density, ponderosa pine, forest improvement cutting.

Thinning study results provide a portion of the information on which timber stand improvement policy is formulated. To be useful these studies should sample a wide range of sites, tree sizes, age classes, and geographic locations in planted and natural stands.

The study reported here is one of a number of thinning experiments established in various stands throughout the Pacific Northwest during the period from 1957 to 1965. This report summarizes initial 11-year results after thinning a 33-year-old ponderosa pine plantation.[1]

STAND HISTORY

The study area is bisected by an intermittent stream drainage called Flat Creek near the middle fork of the John Day River, 25 miles northeast of John Day, Oregon. The stand was established by planting in the springs of 1925 and 1926 after logging and a hot burn. The planting stock was 1-1 and 2-1 from the Wind River nursery located near Carson, Washington. Seed source is uncertain but is believed to have come from the Wallowa-Whitman National Forest. Seedlings were planted with a hoe at a spacing of 6 by 6 feet. On one side of the drainage, slopes are steep with a northeast exposure; on the other, gentle south slopes predominate. Average elevation is about 4, 100 feet.

Early records and photographs indicate that understory vegetation offered little competition to tree growth during the early history of this plantation. Thinning has not appeared to increase growth of competing vegetation appreciably even at the wide spacings. Some scattered *Ribes* bushes may have responded slightly to thinning, but they are so few their competitive effect seems negligible. Few grasses were found on the area, and those present were grazed so heavily that identification was difficult. Other genera occurring on the plantation are *Berberis* (Oregon grape), *Vaccinium* (huckleberry), *Arctostaphylos* (kinnikinnick), *Fragaria* (strawberry), *Rosa* (rose), *Potentilla* (cinquefoil), and *Antennaria* (everlasting). The plant community was identified as mixed conifer/*Calamagrostis*.[2] Thus, an entirely different understory vegetation complex exists on this study than on the thinning study near Bend, Oregon[3] where shrub species bitterbrush, manzanita, and snowbrush make up the *Pinus ponderosa/Purshia tridentata-Arctostaphylos patula* plant community.

The surface soils on the study plots have developed on wind-deposited talus-parent materials. Where the wind-deposited parent materials occur, two buried profiles are present. One profile is developed on wind-deposited material, while a lower, older profile appears to be a residual soil. Textures for horizons developed on wind-deposited parent material range from clay loams to loams, while textures in the oldest buried soil are clay loams and silty clays. Talus parent materials occur mainly on northeast exposures where 5-foot profiles consisted of 70 percent stone. Plots on southern exposures have soils containing only 2 to 5 percent stone. This stone exists in the residual parent material and as outcropping from the residual parent material. Sometimes this stone extends up into the wind-deposited parent material.

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[1] A cooperative research effort between the Malheur National Forest and the Pacific Northwest Forest and Range Experiment Station.

[2] Plant community identified by Frederick C. Hall, Region 6, U.S. Forest Service.

[3] James W. Barrett. Ponderosa pine saplings respond to control of spacing and understory vegetation. USDA Forest Serv. Res. Note PNW-106, 16 p., illus. Pac. Northwest Forest & Range Exp. Stn., Portland, Oreg. 1970.

THE STUDY

Spacings tested were 8.8, 10.2, 12.5, and 17.6 feet (figs. 1 and 2). Each spacing was replicated three times in a randomized block design making a total of 12 plots. Plots consisted of 0.1-acre squares (66 feet by 66 feet), surrounded by a 33-foot buffer strip.

Spacings selected are based on attaining 100, 75, 50, and 25 percent of normal basal area (site index 78)[4] when the average diameter of the stand reaches 8 inches. It was assumed that an 8.8 by 8.8 spacing of 560 well-spaced 8-inch trees per acre would occupy the site rapidly and represent the land's capacity to produce wood fiber, i.e., this high density treatment was to represent a production goal with which to compare the three wider spacings.

In 1959, directly after thinning, five trees per plot were climbed and stem diameter measured at 10-foot intervals to form the basis for a volume equation. In 1965, these same trees plus five more per plot were measured. During the first period, volume was determined by combining all climbed trees (60) into one equation defining volume as a function of diameter and height (D^2H, D^3H, and H^2). During the last period, separate equations were computed for each plot based on 10 climbed trees per plot.

Diameter at breast height and height of all trees on each plot were measured to the nearest 0.1 inch and 0.1 foot, respectively.

Analysis of variance was used to judge treatment effect. Attempts to use stoniness and initial height of the 100 largest trees as covariates failed. Evidently site differences were taken care of by block distinction when the study was installed. Stone content was high on the northeast exposure which made up a block of four plots.

Trees left after thinning were vigorous, full-crowned trees (fig. 3). They contrasted sharply with poorly crowned trees found in adjacent dense natural stands where trees had been subjected to years of suppression.

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[4] Walter H. Meyer. Yield of even-aged stands of ponderosa pine. U.S. Dep. Agric. Tech. Bull. 630 (rev.), 59 p., illus. 1961.

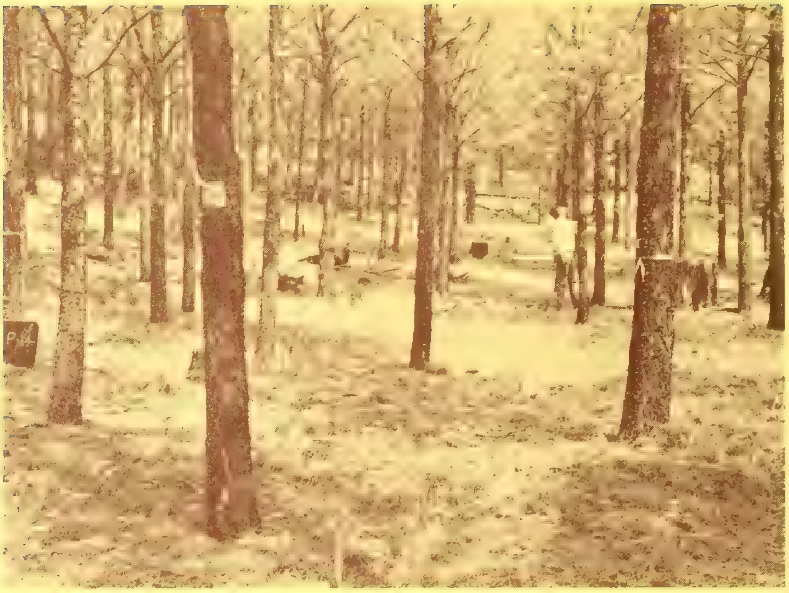

Figure 1.—Stand thinned to 10.2- by 10.2-foot spacing, or 420 trees per acre.

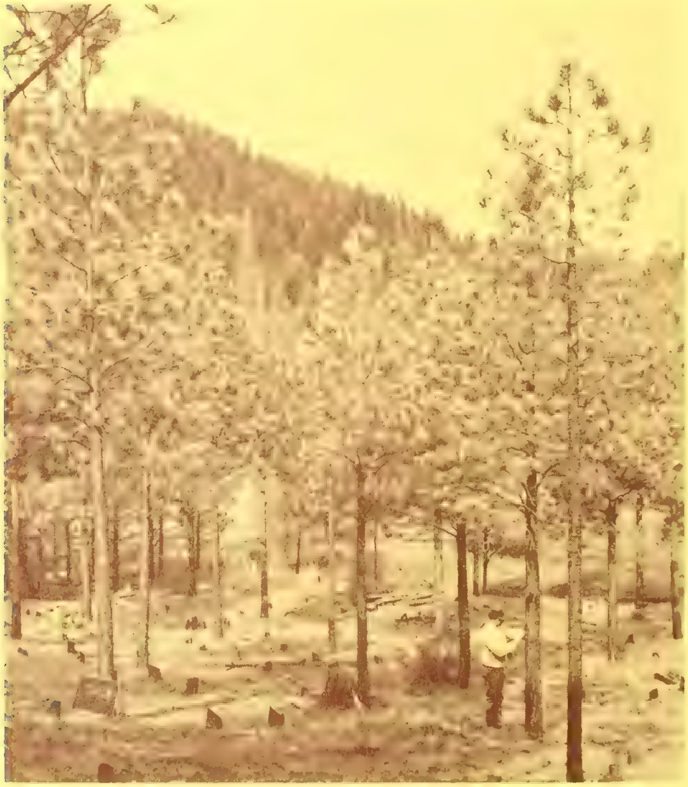

Figure 2.—Stand thinned to 17.6- by 17.6-foot spacing, or 140 trees per acre.

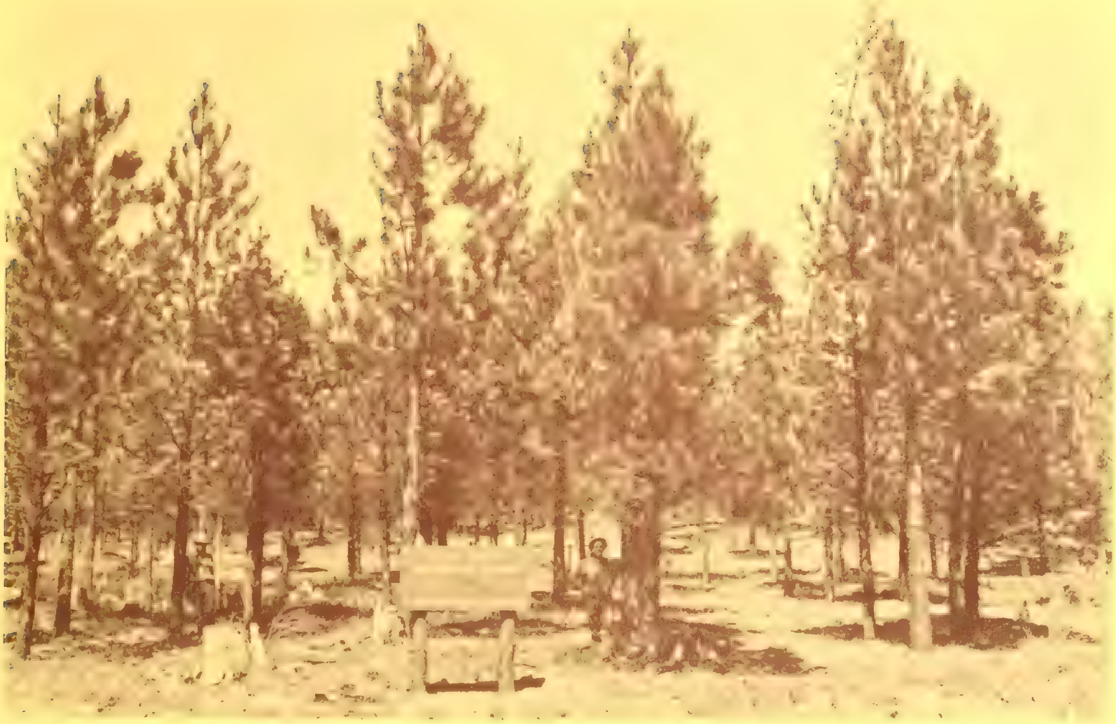

Figure 3.—Most trees left after thinning were full-crowned and capable of responding to the additional growing space provided by thinning.

RESULTS

Directly after thinning, trees averaged 5.5 inches in diameter at the closest spacing and 6.8 inches at the widest (table 1). Basal areas ranged from 92 square feet per acre at the highest density to 35 at the lowest and heights, from 23 to 26 feet. Stands with the closest spacing contained 886 cubic feet per acre compared with only 383 at the widest.

Diameter Growth

Widely spaced trees grew significantly better than narrowly spaced ones during the first and second periods of observation (fig. 4). Also, rate of diameter growth was significantly greater during the second period than during the first. Trees at the widest spacing (17.6 feet) grew at the rate of 2.7 inches per decade during the second period compared with only 1.0 inch for trees 8.8 feet apart.

Individual tree growth ranged from a high of 0.4 inch per year on full-crowned widely spaced trees to no detectable amount on poor-crowned trees at high densities.

Examination of the growth of the 100 largest diameter trees per acre

Table 1.--*Average live stand characteristics per acre directly after thinning, and 6 years and 11 years later*

Treatment		Age	Diameter[1]		Height[2]		Basal area	Bole area	Volume[3]
Spacing (feet)	Trees per acre		All trees	100 largest trees	All trees	100 largest trees			
		Years	*- - Inches*	*- -*	*- - Feet*	*- -*	*Sq. ft.*	*1,000 sq.ft.*	*Cu. ft.*
8.8	560	33	5.5	7.4	22.6	28.5	92.4	10.3	886
		39	6.1	8.2	26.1	33.2	113.6	12.4	1,161
		44	6.6	9.0	30.0	37.8	133.1	15.4	1,605
10.2	420	33	5.7	6.6	20.6	25.2	74.4	7.8	580
		39	6.3	7.4	23.8	29.9	90.9	9.4	739
		44	7.0	8.2	27.1	33.9	112.3	12.1	1,105
12.5	280	33	6.1	6.8	21.8	25.6	56.8	5.8	458
		39	6.8	7.6	25.3	29.7	70.6	7.6	643
		44	7.7	8.5	29.3	34.3	90.6	10.4	1,018
17.6	140	33	6.8	7.4	26.4	28.1	35.3	3.7	383
		39	7.9	8.6	30.7	32.8	47.7	4.7	560
		44	9.3	10.0	35.7	38.2	66.0	6.7	931

[1] Quadratic mean.

[2] Arithmetic mean.

[3] Volume of entire stem inside bark.

shows that growth of these trees was reduced by competition from other trees (fig. 5). For example, the 100 largest trees in the two highest densities grew an average of about 1.4 inches during the first and second periods, compared with 2.0 in the first period and almost 3.0 inches in the second period at the widest spacing.

Height Growth

The effect of spacing on height growth varied (fig. 6). Although trees on the widely spaced plots grew an average of about 1 foot per year during the second period, growth on one plot at the narrowest spacing nearly equaled this. Similar conclusions were drawn when considering only the 100 largest trees per acre (fig. 7).

Height growth averaged greater during the second period for all treatments, although no statistical significance could be attributed to the increase. Three plots grew slightly less during the second period than during the first. Individual tree increments ranged from a high of 1.6 feet per year on several trees at the widest spacing to 0.2 foot on some trees at the narrowest spacing. Great variation in individual tree height growth was observed within plots, and growth appeared more closely related to initial tree size directly after thinning rather than to stand treatment.

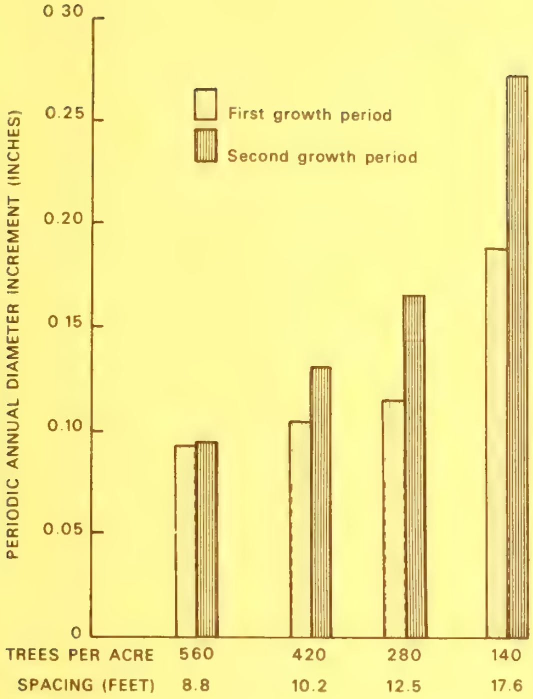

Figure 4.—Average annual diameter increment of all ponderosa pine during the first and second growth periods.

The 100 largest trees from the stand grew substantially more than the stand average at the higher densities, but, as before, treatment did not affect growth (fig. 7).

Mortality

Only five of the 420 trees in the experiment died during the 10-year period of observation. Four of these trees died on plots with the closest spacing where a few suppressed trees had to be left to meet the specified density. This mortality amounted to about 0.9 of a cubic foot per acre per year. There was no mortality at the widest spacing.

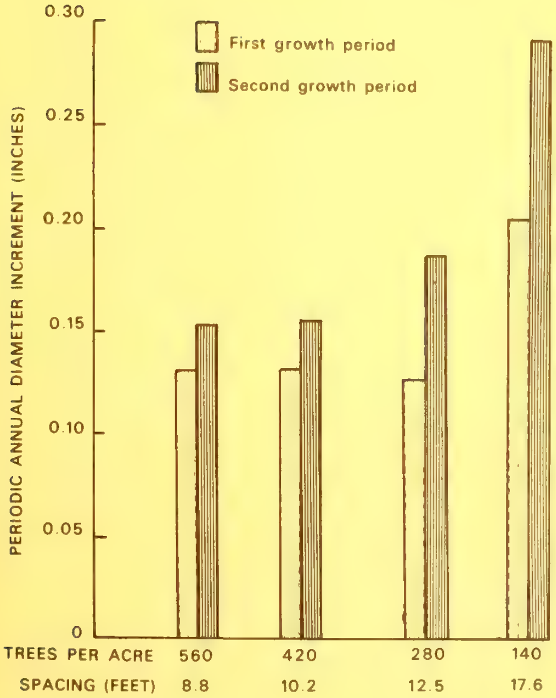

Figure 5.—Average annual diameter increment of the 100 largest diameter trees per acre during the first and second growth periods.

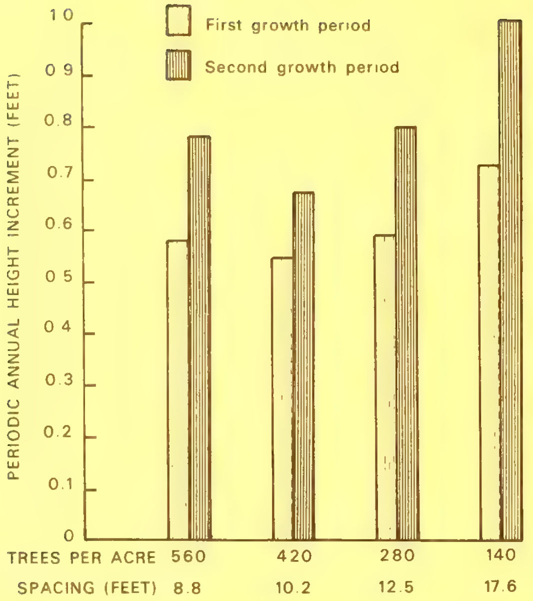

Figure 6.—Average annual height increment of all trees during the first and second growth periods.

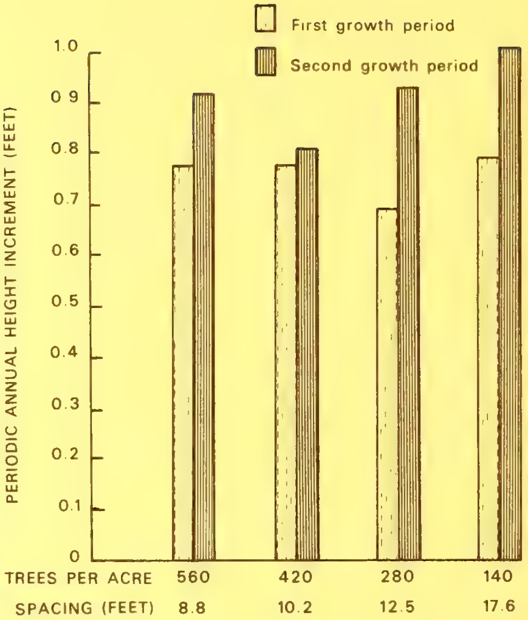

Figure 7.—Average annual height increment of the 100 largest trees per acre during the first and second growth periods.

Cubic Volume Increment

Thinning treatment did not significantly affect cubic volume increment in either period of observation (fig. 8). One hundred forty trees per acre has produced at least 80 percent of the cubic volume grown by 560 trees per acre; thus the capacity of the stand to produce volume has been transferred from many small trees to fewer large trees.

During the first period, the highest density produced about 46 cubic feet per acre per year, with the other three densities producing between 26 and 31 cubic feet. During the last period, roots and crowns probably expanded sufficiently to take better advantage of the additional growing space, and there was a highly significant increase in production from the first to the second period. The highest density averaged about 89 cubic feet per acre per year, with the other three densities averaging 73 to 75 cubic feet.

Extreme soil stoniness probably contributed to reduced wood production on two plots in this experiment. Volume increment on one plot containing 75 percent stone (fig. 9B) was 50 percent lower than the comparable figure for

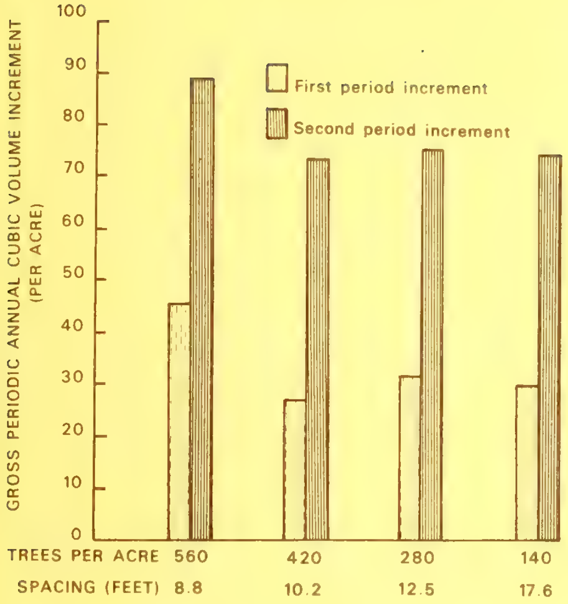

Figure 8.—Periodic annual gross volume increment of ponderosa pine thinned to various spacings during the first and second growth periods.

plots thinned to the same density but situated on stone-free soil. Although the thinned stands on very stony soils appear healthy and vigorous (fig. 9A), volume production was markedly reduced. Evidently stoniness has so lowered soil moisture storage capacity that trees on these sites are deprived of adequate soil water for optimum growth.[5] This condition was evident in reduced height growth where average initial height on stony soil plots was about 6 feet shorter than plots with low stone content.

Understory vegetation on this site is not providing the severe competition to tree growth reported for a comparable study near Bend, Oregon.[6] This may be due, in part, to heavy grazing since this study is located close to water. In the present study there was significant trend toward more increment for the largest trees as stand density was decreased (fig. 10). For example, the 100 largest trees, in a stand containing 420 trees per acre, grew at the rate of 33 cubic feet per acre per year, and this increased to 45 and 63 cubic feet in stands containing only 280 and 140 trees. However, in central Oregon where shrubs are more abundant, wide spacing stimulated understory vegetation which offered as much competition as many more trees. In the present study, understory competition appears to be almost negligible since the growth curves in figure 10 have a fairly smooth upward trend with decreasing density. If invading understory vegetation were serious competition, growth curves in figure 7 would be expected to be more nearly flat, as reported by Barrett.[7]

It should be recognized, however, that soils of the study reported here and the one in central Oregon are quite different. The latter occurs on a dacite

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[5] C. T. Dyrness. Hydrologic properties of soils on three small watersheds in the western Cascades of Oregon. USDA Forest Serv. Res. Note PNW-111, 17 p., illus. Pac. Northwest Forest & Range Exp. Stn., Portland, Oreg. 1969.

[6] See footnote 3.

[7] See footnote 3.

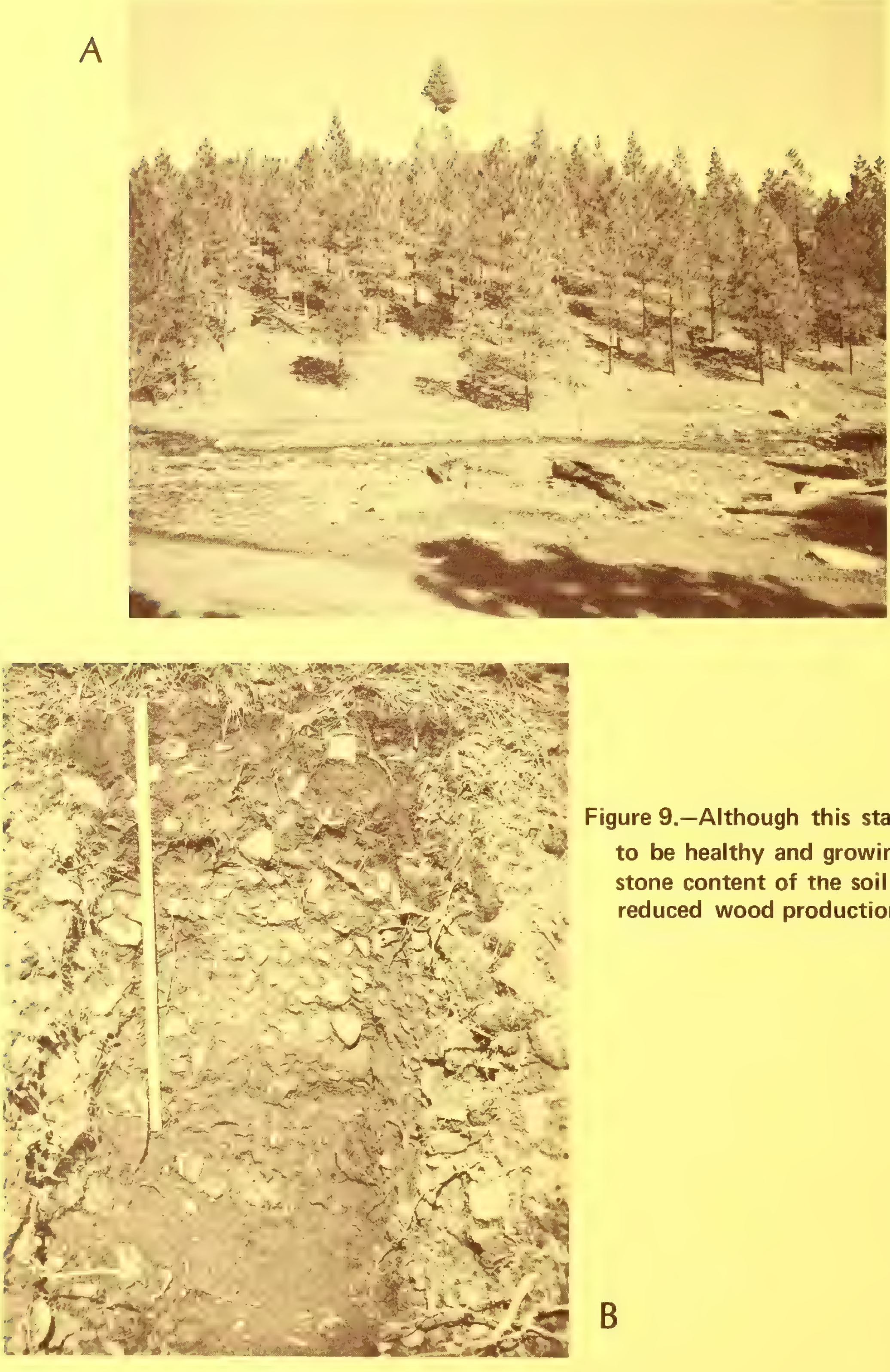

Figure 9.—Although this stand appears to be healthy and growing well (A), stone content of the soil may have reduced wood production (B).

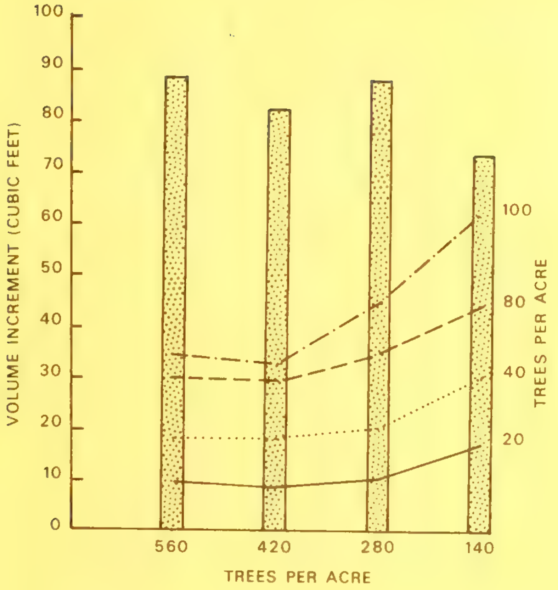

Figure 10.—Periodic annual volume increment of ponderosa pine saplings thinned to various spacings (1965-69). Bars show increment for total number of trees at each spacing. Points within bars show increment of the stated number of the largest well distributed trees within the stand. (Volume increment for the 420 and 280 trees per acre treatments does not agree with that shown in figure 8 because data from the two plots containing large amounts of stone were excluded from averages.)

pumice mantle averaging 33 inches thick underlain by a sandy loam Paleosol. Some of the horizons of the pumice mantle are rather sterile, and the moisture characteristics of the two soils on the two study areas are probably quite different. Therefore, some of the growth difference between the two studies may be explained by factors other than competition from invading vegetation.

DISCUSSION AND CONCLUSIONS

This demonstration suggests that wood production in ponderosa pine plantations, where tree crowns are well formed and full, recovers rapidly after thinning even though only 140 trees per acre are left. Furthermore, this experiment supports the theory that in vigorous young stands the same amount of periodic annual cubic volume can be produced over a wide range of tree densities. Although the heaviest thinning constituted an initial reduction in basal area of 65 percent, this treatment produced 80 percent of the volume grown by four times as many trees. Even more important is the fact that a commercial thinning will probably be possible in another decade. Basal area will probably have attained 100 square feet and average diameter of the stand should be approaching 12 inches.

The planted ponderosa pines in this experiment have developed without the severe suppressional period experienced by many crop trees in natural stands[8] and have therefore been able to respond quickly to thinning. Foresters should be cautious about applying growth results reported here to thinned natural stands with short, suppressed crowns. Once trees in thinned natural stands have recovered from the suppressional period, spacing-growth relationship between the two stands should be similar.

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[8] James W. Barrett. Dominant ponderosa pines *do* respond to thinning. USDA Forest Serv. Res. Note PNW-9, 8 p., illus. Pac. Northwest Forest & Range Exp. Stn., Portland, Oreg. 1963.

The dense parts of this plantation should have been thinned at an earlier age to maintain a reasonable diameter growth. Before thinning and where little mortality had taken place, diameter growth rates were less than 1 inch per decade. Outside the study area where spacing was much wider than 6 by 6 feet, average tree diameters were sometimes twice that found in the stand, with negligible mortality. Thus planting fewer trees would probably have resulted in a much larger average tree at age 33.

Planting ponderosa pine on excessively stony soil does not appear to be an economically sound practice when wood production is the principal objective. It is doubtful that a merchantable log will ever be produced in a reasonable length of time on these extremely stony soils. On the other hand, such land uses as watershed, recreation, and wildlife may justify the expenditure for reforestation.

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ASKA OREGON WASHINGTON

PACIFIC NORTHWEST
FOREST AND RANGE
EXPERIMENT STATION

USDA FOREST SERVICE RESEARCH NOTE

PNW-180 June 1972

A RECORDING SOIL MOISTURE TENSIOMETER

by

William J. Walkotten, *Forestry Research Technician*

ABSTRACT

A recording water-saturated porous cup tensiometer that operates in the negative pressure range of a mercury manometer-type tensiometer provides a continuous record of soil moisture tension for periods up to 31 days. This instrument detects small moisture changes and diurnal fluctuations; it has also shown rapid response to increasing soil moisture during rainfall. Parts and materials for construction cost less than $150.

KEYWORDS: Tensiometer, soil moisture, soil management.

INTRODUCTION

Some remote instrumented sites in Alaska require recording gages capable of reliable performance for extended periods of time. Weather conditions, absence of electric power, and transportation problems have led to the development of a variety of new instruments and modification of commercial instruments to fit our needs. One of

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these, the recording soil moisture tensiometer (fig. 1), built in our laboratory, has shown trouble-free performance in a variety of field conditions.

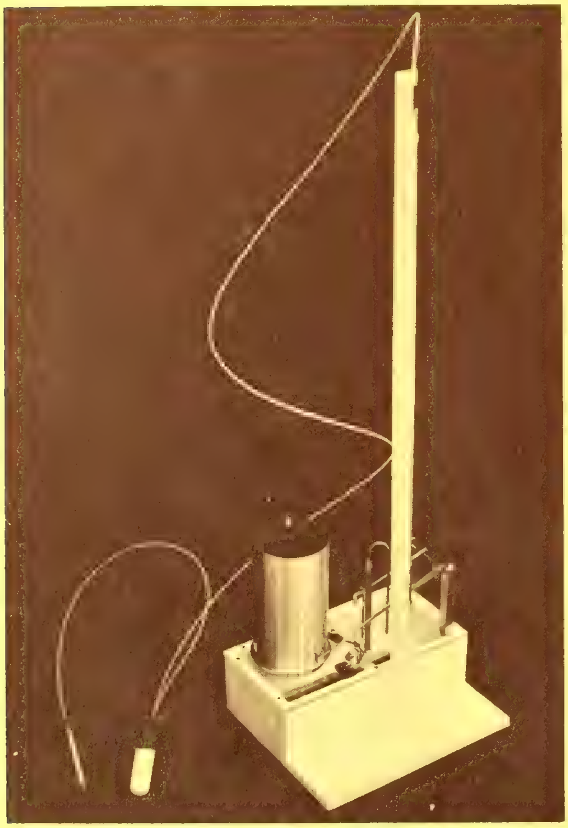


Figure 1.—The recording soil moisture tensiometer.

The operating principle of the recorder is simple: The desorption of a water-saturated porous cup causes a negative pressure within a closed system; this pressure can be detected with a mercury manometer and measured on a graduated scale (Richards 1949). Volume change in the manometer storage cup is recorded, through a float-and-lever system, as an ink line trace on a chart. A graduated scale is provided for direct reading of soil tension and chart calibration.

DESCRIPTION

The simple-design recorder can be built with readily available materials in a shop equipped with wood and metal working equipment by anyone familiar with these tools. It is composed of four basic systems: (1) the porous cup and related tubing; (2) the manometer, scale, and mercury storage cup; (3) the float-and-lever system and pen; and (4) the chart drum and drive. These systems are mounted on a plywood and plastic base.

The porous cup (fig. 2) is placed in the soil at the desired depth, and the transfer of water through the cup changes the water volume in the manometer system. Two small nylon tubes extend to the soil surface and connect the porous cup to a flushing tube and the recorder. The connecting tubing is cut to lengths suitable to the particular installation. The flushing tube is used primarily to fill the porous cup and balance the manometer system. The recorder tube is sealed to the top of the glass manometer at the recorder.

The manometer system consists of a short length of 3/4-inch inside diameter plastic tubing with a plastic cap cemented on the bottom for the storage cup, 5/16-inch Nalgene tubing and connecting

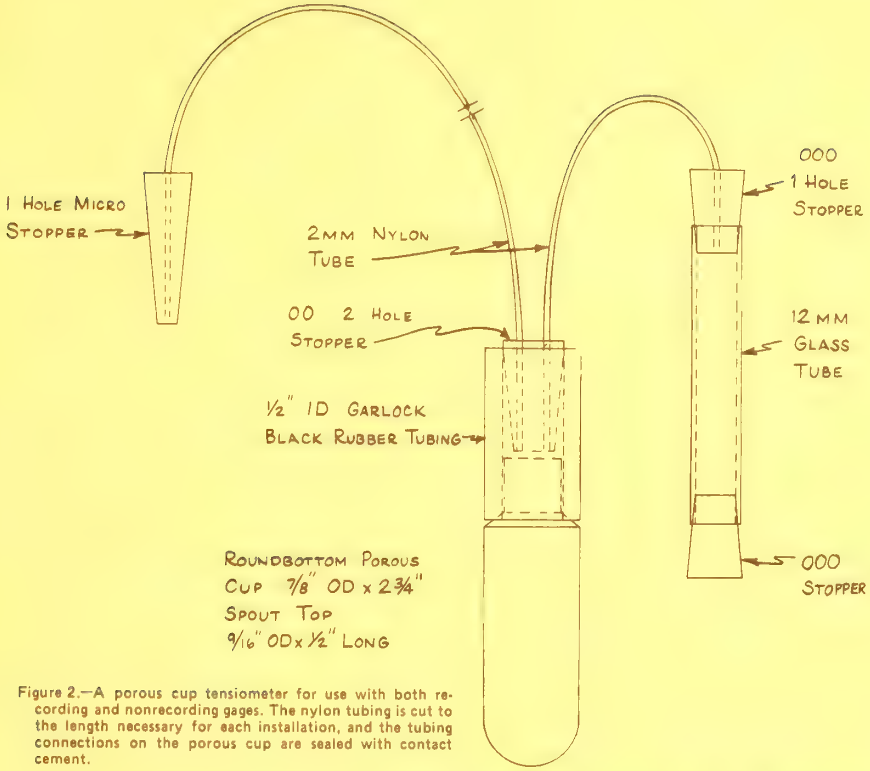

1 Hole Micro Stopper
2mm Nylon Tube
00 2 Hole Stopper
½" ID Garlock Black Rubber Tubing
Roundbottom Porous Cup ⅞" OD x 2¾" Spout Top 9/16" OD x ½" Long
000 1 Hole Stopper
12 mm Glass Tube
000 Stopper

Figure 2.—A porous cup tensiometer for use with both recording and nonrecording gages. The nylon tubing is cut to the length necessary for each installation, and the tubing connections on the porous cup are sealed with contact cement.

fittings, and 8-mm. glass tubing for the manometer tube (fig. 3). The storage cup is cemented in a hole through the base at a depth to allow full swing of the float-and-lever system, and a Nalgene fitting is threaded into a shallow-cut 1/4-inch Female National Pipe thread in the bottom cap. The shallow pipe thread is necessary so the Nalgene fitting does not protrude through the cap and limit the action of the float. These tubing and fitting sizes give the proper volume relationship between the mercury storage cup and glass manometer tube for a full chart-width trace, thus producing maximum sensitivity. Plastic tubing and fittings avoid possible problems caused by the ability of mercury to amalgamate with most metals. Nalgene also forms a leak-proof seal to

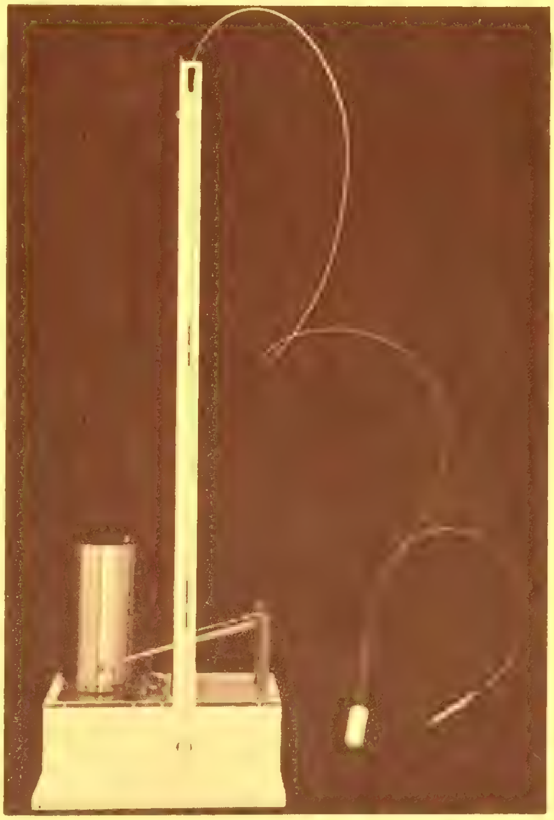


Figure 3.—Front view of recording soil moisture tensiometer showing glass manometer tube and scale.

the 8-mm. glass tube without breaking it. The scale behind the manometer tube is for direct reading of soil moisture tension. In this example it is 760 mm. long, divided into 100 parts (Richards 1942).

The float-and-lever system provides the mechanical link necessary to operate the pen arm (figs. 4, 5). It is positioned on the base for proper leverage, easy adjustment, and elimination of any lash in the system. The float is machined from Teflon to fit inside the storage cup, with a hole drilled through the center and threaded for fastening and adjustment on the float rod. Lever system parts are machined from brass rod and brass stock, and the pen arm and point are standard recording rain gage parts. The location of the axle shaft center line of the lever system is controlled by the length of the pen arm. Careful placement provides a proper chart trace.

The chart drum and drive are a commercial unit that is available with a variety of rotation speeds from one per day to one per 31 days. The battery-powered drive has proven accurate and reliable. No chart is available with the proper horizontal or tension lines for this recorder, but the curved vertical time lines are used on any chart that matches the drum rotation. The chart is calibrated by direct reading of the manometer scale with this reading noted on the chart. Charts are calibrated separately for each recorder and site location.

The recorder base is made from 1/2-inch exterior plywood and 1/4-inch clear plastic. Careful construction of the base is important to provide a rigid and level platform for the clock-and-lever system. A cover to protect the vital parts of the recorder is made from 3/16-inch clear plastic, which also allows visual observation of the recorder with a minimum of disturbance. The clock-drive battery is mounted inside the base. A three-point leveling screw system and a bubble level mounted on the base have facilitated rapid setup of the recorder in field installations.

OPERATION

The porous cup is placed in the soil. The recorder is placed nearby, leveled, and mercury added to the storage cup to a point where the pen is about 1-1/2 inches from the top of the chart. At this time the manometer system is checked for any mercury leakage. Deaerated water, added at the top of the 8-mm. glass tube until the tube is full, displaces some of the mercury and brings the pen near the top of the chart. Both the pen and the manometer scale can now be zeroed by adding or removing mercury, turning the plastic float on its threaded shaft, and adjusting the scale on its support. The porous cup is

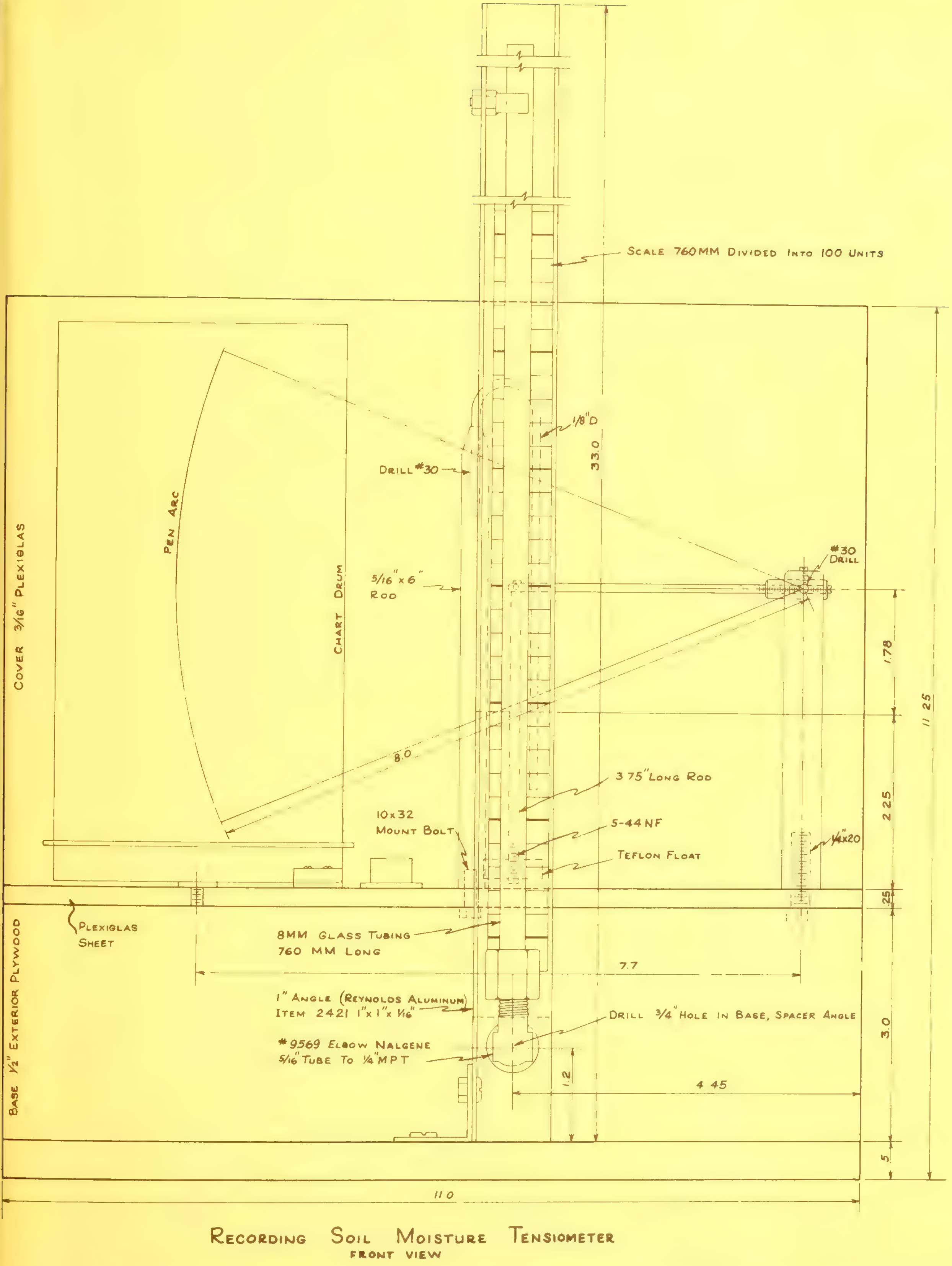

Scale 760MM Divided Into 100 Units
1/8"D
33.0
Drill #30
Pen Arc
Cover 3/16" Plexiglas
Chart Drum
#30 Drill
5/16" x 6" Rod
1.78
11 25
8.0
3 75" Long Rod
2 25
10x32 Mount Bolt
5-44 NF
1/4x20
Teflon Float
.25
Plexiglas Sheet
8MM Glass Tubing 760 MM Long
7.7
Base 1/2" Exterior Plywood
1" Angle (Reynolds Aluminum) Item 2421 1"x 1"x 1/16"
Drill 3/4" Hole in Base, Spacer Angle
3.0
#9569 Elbow Nalgene 5/16" Tube To 1/4" MPT
1.2
4 45
.5
11 0
Recording Soil Moisture Tensiometer
Front View

Figure 4.—Construction plans for recording soil moisture tensiometer (front view).

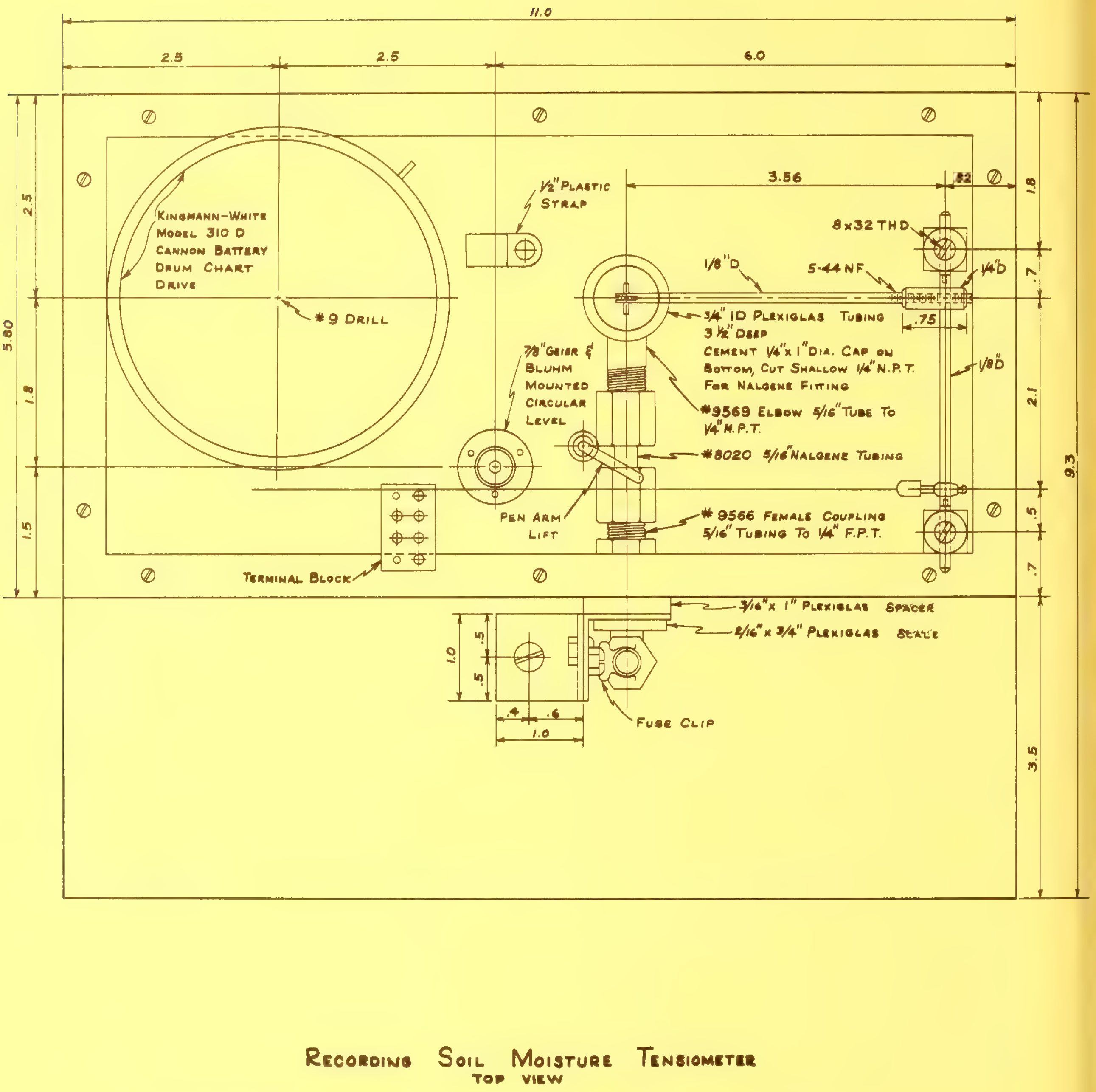


Figure 5.—Construction plans for recording soil moisture tensiometer (top view).

then filled by flushing deaerated water into the short "flushing tube," through the cup, and out the recorder tube in sufficient quantities to remove entrapped air. Flushing is best done with a squeeze-type plastic bottle placed in the end of the flushing tube. Then the stopper in the flushing tube is replaced, and the recorder tube is fitted into the top of the 8-mm. manometer tube through a microstopper. The recorder is then ready for field operation. Sealing the microstopper into the manometer tube will cause a slight increase in pressure, but water soon passes through the porous cup and will reach equilibrium with the surrounding soil.

As moisture tension changes within the soil, the water volume (and thus the mercury location within the manometer system) changes accordingly and adjusts the mercury level in the connected storage tube where a self-lubricating plastic float actuates the pen arm of the recorder.

Zero tension is indicated at the top of the chart when the mercury storage cup contains the most mercury. Negative pressures cause the pen to fall as the mercury is drawn up into the manometer tube.

RESULTS

Several of these recorders have been operated in southeast Alaska and one near Fairbanks, Alaska, during the past few seasons. These have provided a continuous record of moisture tension through most of the growing season, giving detailed information about rate of penetration and extraction of water from the soil. A sample of changes in soil moisture potential, as recorded by this instrument, is shown in figure 6. Both rainfall and tensiometer variations were recorded over a 7-day period at this forested site. Early in the week, soil tension increased at a slow but steady rate in response to soil drainage. An abrupt decrease in tension occurred about midweek in response to increasing rainfall as the wetted horizon passed the porous cup. The interval for the peak of the tension decrease was about 6 hours after the beginning of the rain shower. The soil reached a nearly saturated condition and then, as precipitation decreased, tension increased again.

The main values of this type of tensiometer recorder are that the device is simple in design and construction (Bianchi and Tovey 1968), and the continuous tension record is detailed enough to detect changes as small as 0.005 atmosphere when a good pen is used on the pen arm (Remson and Randolph 1958). The effective range of the recorder is the same as any porous cup tensiometer, with failure at about 0.75 atmospheres when air enters the system through the porous cup.

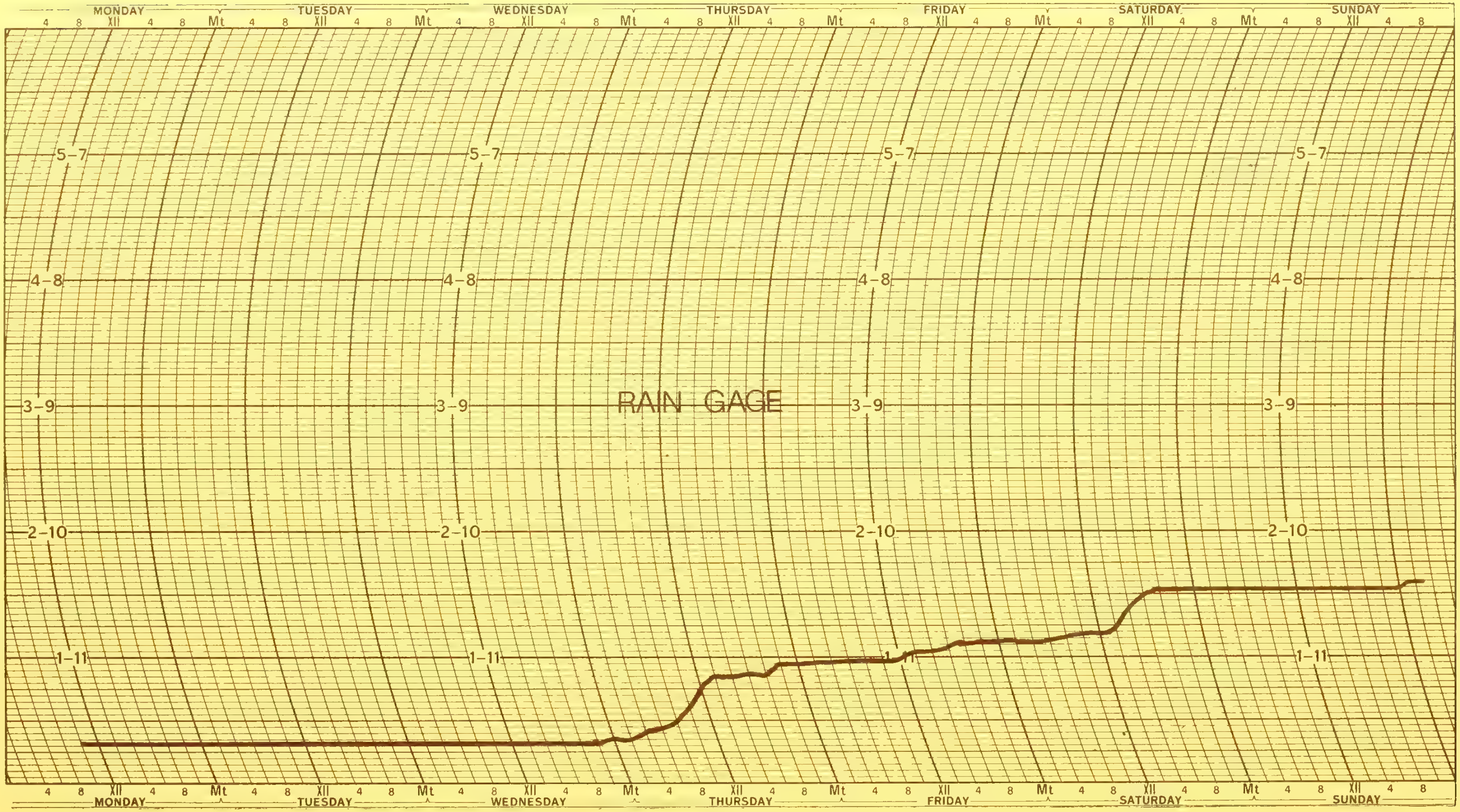
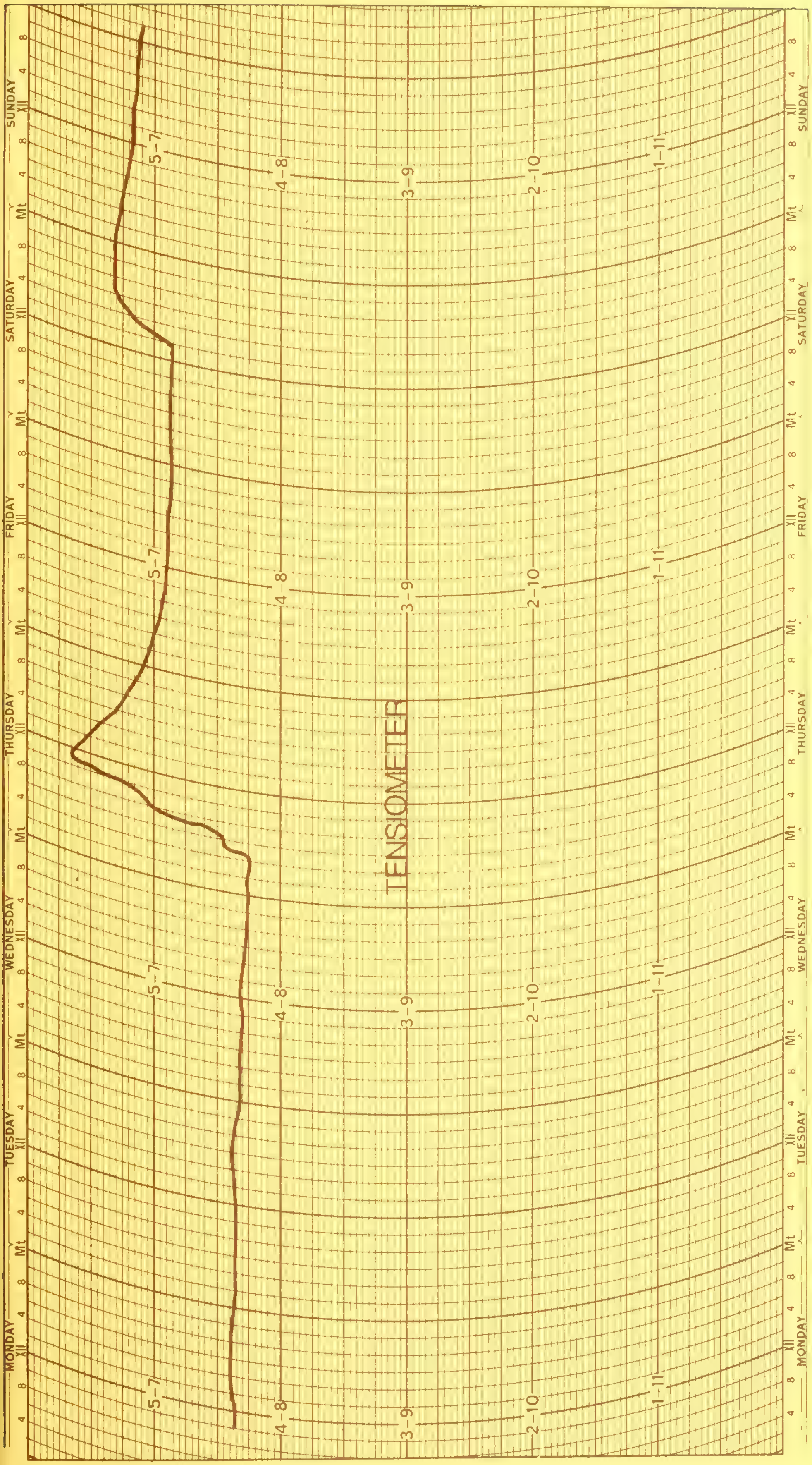


Figure 6.—Soil moisture tension change response to rainfall on a mixed spruce-hemlock forested site near Juneau, Alaska. *A*, Rain gage; *B*, tensiometer.


TENSIOMETER
MONDAY
TUESDAY
WEDNESDAY
THURSDAY
FRIDAY
SATURDAY
SUNDAY
Mt
XII
4
8
5-7
4-8
3-9
2-10
1-11

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1958. Root growth near tensiometer cups as a cause of diurnal fluctuations of readings. Soil Sci. 85: 167-171, illus.

Richards, L. A.
1942. Soil moisture tensiometer materials and construction. Soil Sci. 53: 241-248, illus.

______ 1949. Methods of measuring soil moisture tension. Soil Sci. 68: 95-112, illus.

GPO 986-004

RECORDING SOIL MOISTURE TENSIOMETER
PARTS LIST[1]

	Approximate cost
Model 301-D Drum Chart Drive	$85.00
and Model 95 Belfort Pen	4.00
Kingmann-White Inc. 653 S. Melrose Street Placentia, Calif. 92670	
Pen Arm Ass'y., Part #992, complete w/pivot clamp and set screw, Belfort cat. #5-780	4.00
Belfort Instrument Co. 2 N. Central Avenue Baltimore, Maryland 21202	
Nalgene Fittings	
2 ea. #9569 Elbow 5/16 tube to 1/4" M.P.T.	1.00
1 ea. #9566 Female Coupling 5/16 tube to 1/4" F.P.T.	1.00
#8020 Nalgene Tubing (about 2")	.50
Nalgene Company 75 Panorama Creek Drive Rochester, N.Y. 14625	
Plexiglas 1 Base 1/4" by 5-5/8" x 11" 1 tube 3/4" ID 3-3/4" long Cover 2 side 3/16" by 7-5/16" x 11" 2 end 3/16" by 5-1/4" x 7-5/16" 1 top 3/16" by 5-5/8" x 11" 1 Scale & Spacer 3/16 by 3/4" by 36"	From local suppliers Prices from $1 to $2/sq. ft.
Also assorted plywood, bolts, screws, brass rod, fuse clip, aluminum angle, 8mm. glass tubing, paint, 1# mercury	25.00

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[1] *Mention of product or company does not imply endorsement by the U.S. Department of Agriculture to the exclusion of other products.*

	Approximate cost
Teflon Rod #9Z200CF, 1 inch dia. Allied Electronics 100 N. Western Ave. Chicago, Ill. 60680	$6.55/ft.
Circular Level, 7/8", #2-6000 Geier & Blunm, Inc. 594 River Street Troy, New York 12180	2.00
Nylon Tubing Commercial Plastics & Supply Corp. 630 Broadway New York 12, N.Y. 10007	Total supplies about $2 per unit
Round Bottom Cups #2131 Soil Moisture Equip. Co. 3005 De La Vina Street Santa Barbara, Calif. 93105	
Rubber Tubing, Garlock, Black & Glass Tubing & Pliobond #56421 Scientific Supplies Co. 600 Spokane Street Seattle, Wash. 98134	
Stoppers Arthur H. Thomas Co. Box 779 Philadelphia, Pa. 19105	